User Experience for Elephants: Researching Interactive Enrichment through Design and Craft

Thesis

User Experience for Elephants

Researching Interactive Enrichment through Design and Craft

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Thesis submitted for the degree of Doctor of Philosophy

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November 2020

Abstract

This thesis explores the challenge for humans of designing and crafting interactive enrichment systems for elephants housed in captivity.

Captive elephants may have limited opportunity to express a full range of natural behaviours and therefore benefit from well-designed environmental enrichment. We asked whether technology could support the design and development of novel enrichment for elephants and investigated what kinds of technology-enabled systems would hold their interest. Crucially, these systems were designed to provide the elephants with opportunities to make and enact choices – giving them more control over what happened in their environment.

After researching wild elephant lifestyle and characteristics, our fieldwork started with an ethnographic study of captive elephants. We then followed an exploratory approach: Research through Design and Craft. Over several years, a range of interactive systems were crafted for elephants. Each device included embedded technology that enabled elephant interactions to be captured and mapped to associated system outputs. Elephants and their keepers were involved in this cyclical process, and the elephants' reactions to the devices were noted and interpreted, giving rise to insights that informed the subsequent designs.

Analysis of the design and development of the enrichment systems revealed important interface attributes and design considerations that we describe in this document. Finally, we offer five contributions for the ACI community: (i) *Research through Design and Craft* methodology, which was developed and tested over several years; (ii) *ZooJam* workshops, which were organised with colleagues over three years; (iii) six key principles of interaction design for ACI development – *consistency, differentiation, graduation, specificity, multiplicity* and *affordance*; (iv) an exploration of *More than Human Aesthetics* focusing on performative aesthetics; (v) a prototype deck of *Concept Craft Cards* that share theoretical and practical topics with other designers and developers.

Acknowledgements

First of all, I'd like to thank my supervisors, Clara Mancini and Helen Sharp, for guiding me on this journey, for their patience and attention to detail, for sharing their wisdom, for being awesome editors and co-authors on numerous publications and for being such interesting company during lengthy virtual meetings. I've always looked forward to our discussions and I have learned much about the value of making time to reflect, even when life is packed with other essential activities. I'd also like to acknowledge the advice and thoughtful suggestions offered by my external examiners, Martin Kaltenbrunner and Janet van der Linden, which set me thinking even more about aesthetics.

Elephants and their carers have to come next – especially Valli at Skanda Vale and her companion, Lakshmi. Without the willing participation of curious elephants and their loving keepers, there would be no project. The Brothers at Skanda Vale have dedicated a huge part of their lives to caring for Valli and Lakshmi, and they made me feel incredibly welcome, year after year, button after button. Thank you to everyone in that enlightened community! Thank you as well to the following elephants and zoo personnel: Tanya, Opal, Tembo, Zola and Head Keeper Claire at Colchester Zoo; Janu, Machanga and Elephant Manager Sandra at Noah's Ark; Mondula, Toto, Head of Large Mammals Chris Hales and Head of Research Alistair Gillies at Blair Drummond Safari Park; Operations Manager Gerry Creighton at Dublin Zoo and Head Elephant Keeper Andy and colleagues at Twycross Zoo.

Meeting the team at Skanda Vale was arranged for me by Mark Kingston-Jones, co-founder of Team Building with Bite and an enrichment specialist with The Shape of Enrichment, to whom I offer a big thank you. I attended a workshop run by Mark in 2014 and collaborated with him on our first ZooJam in 2016; his enthusiasm, knowledge and professionalism are inspiring. Mark also introduced me to the amazing Valerie Hare, who co-founded SHAPE and collaborated with us on our third ZooJam in 2018. It was wonderful to meet her – thanks Valerie! Special thanks go to all the colleagues who have worked with me on ZooJams over the years: Mark Campbell, Sarah Webber, Heli Väätäjä, David Schaller, Sofya Baskin, Adrian Cheok, Eleonora Nannoni, Billy Wallace, Anna Zamansky, Reinhard Gupfinger and Paul Kendrick. And thanks to all the animal and ACI experts who contributed briefs for ZooJam participants: Sconaid Wastie, Sophie Collins and Sian Phillips from RSPCA, Matt O'Leary from ZSL, Michelle Westerlaken, Lisa Yon from EWG and Robert Young. And indeed, thank you to all the fabulously creative participants, whose contributions have enriched this work.

Lisa Yon and the BIAZA EWG (Elephant Welfare Group) deserve a special thank you. Lisa has given me some great advice and support over the years, initially by organizing an EWG virtual meeting at the start of the project, so I could discuss ideas with members (thank you Ros Clubb, Oliver Burman, Samantha Bremner-Harris). Other professional people who have taken time to talk to me include Hannah Buchanan-Smith from Stirling University, and Vicky Taylor, Neil Smith and Duncan Banks from The Open University. In 2016, Lisa Yon arranged for me to work with one of her students, Ashley Bryant, to test some audio enrichment at Noah's Ark Zoo. Ashley's help with testing and data collection was an invaluable addition to the work.

Another person who helped with the development of an enrichment concept was Chris Hosegood, technician at make.WORKS, our London Metropolitan University creative workshop space. He took the slider blueprint and was able to craft an elephant-sized working prototype – many thanks, Chris! I also offer thanks to my various line-managers and Heads of School at London Metropolitan University, for offering encouragement to undertake this research and for supporting tuition and conference attendance. Thanks to James King, Saeed Taghizadeh and Pete Petitt for their advice on electronics. And thank you to my other Londonmet colleagues who regularly ask me for updates and humour me every time I tell them another elephant story…

I would also like to thank those many colleagues, old friends and ACI compatriots who have been travelling a parallel PhD path at a similar time. You have all motivated me to continue, as we have shared each other's triumphs and occasional rewrites!

Finally, of course, I must thank my family, including our dog, Skomer. Thank you, Skomer, for being a temporary tester when there were no elephants around and for delighting us with your boundless energy and love for life. Thank you, Dom, for patiently helping craft early button frames in the back garden and especially for agreeing to come to Namibia with me as an EHRA (Elephant Human Relations Aid) volunteer. We worked with EHRA for a week, then hired a car and went travelling and camping with our kids – a wonderful experience, like living in a wildlife documentary. Thank you, Sally O'Riordan, for letting me stay in your house before lockdown to write up this thesis and for making me delicious suppers!

Thank you to my dear parents, Joyce and Mike, for their gift of making me value education and independence. Thank you to my incredible children, Clyde and Linton, for spurring me onwards, even if it was unintentional. I didn't give a hoot if they said I was eccentric, but I'd never want them to think I'd given up on a dream. I hope I've shown them some of the passion, drive, bloody-mindedness, slog, willingness to learn, willingness to compromise and most of all, the satisfaction that comes from working with others towards a goal that you really care about. If my modest contribution raises awareness of the potential for humans to improve the welfare of other species, then I feel proud. But I couldn't have done it without you all.

With love XXXXX.

Dedicated to BFFs
Dougal, Skelligs, Skomer

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Introduction

This research explores the potential for using technology to support the delivery of novel environmental enrichment experiences for elephants housed in captivity. In particular, it aims to enhance their welfare by providing them with meaningful choices and opportunities to control environmental features, thereby offering them cognitive and sensory enrichment. Our work falls into the area of Animal-Computer Interaction (ACI: Mancini, 2011), whose aim is designing interactive technology to improve animal welfare and human-animal relations.

Our investigation into high-tech devices for elephants aims to contribute towards the development of a methodological approach for designing smart and playful enrichment for all species. However, this raises an important question: can technology-enabled environmental enrichment ever be appropriate for an undomesticated captive animal, which would never have cause to interact with such a system in the wild? We argue that technology can mitigate some of the limitations imposed by living in a restricted environment, by mimicking challenges that cannot be presented in captivity such that the sensory, cognitive and physical exercise is similar to that which would occur in the wild, even if the process is different and uses 'unnatural' materials (French et al., 2016). This idea has already been explored with a variety of species; for example, Kim-McCormack et al. (2016) highlight the relevance of digital technology for providing dynamic and flexible enrichment in the context of captive primates, while Kingston-Jones et al. (2005) endorse the use of technology to support enrichment for lions.

Figure 1: Asian elephants at Dublin Zoo, 2016

It should be noted that the idea of keeping elephants in captivity at all is refuted by some experts in the field. For example, the Elephant Voices Organisation comments:

'*An excellent alternative to a traditional elephant exhibit in a zoo is the creative presentation of the captivating world of wild elephants through an advanced multimedia elephant information center … Since captive elephants are extremely expensive to keep, and their housing tremendously costly to construct and maintain, the funds necessary for a multimedia venture should be available. The educational value of a facility like this have the potential of being far greater than an exhibit with a couple of desultory elephants in a small enclosure.'* (ElephantVoices.org)

In Europe and the United States, it is now most unusual to capture wild animals and place them in zoos. Nevertheless, the current state of affairs finds a number of animals kept in captivity around the world, many of whom would be unable to exist independently. Zoos and wildlife parks sometimes look after elephants that have been rescued from circuses, elephants that have been orphaned, elephants that have been transferred from other institutions and elephants that have been born in captivity.

For these institutions, elephants are a status symbol – a 'flagship' species that is believed to increase the number of visitors and inspire people. Having such a major attraction fits well with zoos' other missions (apart from entertainment). In addition to maintaining excellent welfare standards, AZA-accredited institutions must demonstrate participation in conservation programmes, development of educational activities for target audiences and commitment to scientific research (AZA.org)

We continue this chapter by explaining in more detail the motivation for our work, then providing an overview of the research, including our key questions, and finally by presenting an outline of this thesis.

1.1 Motivation

Elephants are known for their cognitive and social complexity, demonstrating sophisticated communication skills, problem-solving abilities and a capacity for empathy (Plotnik, 2010; Poole & Granli, 2008). They are also playful, engaging in locomotor, object and social play all their lives (Lee & Moss, 2014). These behavioural characteristics imply that elephants might be capable and willing to engage with a technologically enhanced playful system as well as potentially benefitting from the experience.

Humans keep small populations of elephants in captivity in zoos worldwide. This course of action enables zoos' mission statements, which typically include undertaking research and conservation while offering education and entertainment to the public. It is widely accepted that we have a duty of care towards those animals we keep in captivity, which means ensuring that welfare needs are met, by securing the "Five Freedoms" (FAWC Report, 2009):

1. *from* hunger and thirst
2. *from* pain, injury and disease
3. *from* fear and distress
4. *from* discomfort
5. *to display natural behaviours*.

This last freedom may be the hardest to meet, especially for some species, since captivity inevitably reduces an animal's opportunities for freedom of expression – the ability to make choices and to control its actions and environment.

In the wild, female African and Asian elephants live in matriarchal herds all their lives. Males leave the herd as "teenagers" to become independent, often forming bachelor groups. For elephants, living in the herd provides cognitive and sensory stimulation as well as security and purpose. Herds are a close community with a strong hierarchy, where the elephants continuously 'talk' to each other in low rumbles (Soltis, 2005). It has been shown that an individual can identify up to seventy other affiliated animals, as well as being able to understand the meaning of the acoustic signals being made and respond appropriately. Communication is an important feature of life within the herd, contributing to fitness by supporting relationships, enabling collaboration and the sharing of resources and information. Interpreting and responding to acoustic signals are therefore key skills for an elephant to develop.

Zoos and wildlife parks currently offer their elephants a wide range of low-tech environmental enrichment such as raised baskets of straw (for food and exercise) and hanging tyres (for object and locomotor play), the general purpose of which is to enhance the quality of care by providing stimulation that encourages species-specific behaviours. However, it can be challenging to offer herd animals a truly social experience if they are housed in small numbers. In response to this challenge, this work was motivated by the assumption that there may be welfare benefits for captive elephants (with minimal extended family and fewer opportunities for acoustic stimulation) from interventions that afford them the opportunity to engage with a system designed to offer appropriate auditory and cognitive stimulation. While it was beyond the scope of our work to replicate the experience of living in the wild, we hypothesized that it might be possible to offer the animals enrichment that mitigated some of these privations, albeit in an 'artificial' way.

When developing technology-enabled enrichment for other animals, there are two possible approaches: (i) to try and create a superficially naturalistic simulation of reality, equivalent to some physical or virtual simulated environments for humans, or (ii) to design an abstract experience that requires the player to utilise physical and mental skills that they would develop in a natural environment. Taking an animal-centred point of view, we chose to emphasise enrichment that offered opportunities for the animal to demonstrate natural behaviours, rather than trying to create a setting that superficially resembled their natural environment, even though this might be educational for the public. Such an approach can be beneficial for the animals involved and, indeed, is endorsed by Kingston-Jones (SHAPE of Enrichment), who has pointed out that the Gorilla enclosure of the Howletts Wild Animal Park is completely unlike a natural environment, yet provides excellent opportunities for the inhabitants to exercise and play. Similarly, Martin & Shumaker (2018), who developed interactive games for the enrichment of chimpanzees living in captive settings, explain how computer tasks for great apes can promote their welfare through what they term *functional naturalism*.

It was therefore of little consequence if the experience was completely novel for an elephant (wild elephants would never normally play with computers) as long as the animal was stimulated in an agreeable way and found the system straightforward to use by performing variations of her normal behaviour. In this regard, we made the following assumptions: (i) the provision of novel environmental enrichment is a valuable goal; (ii) interactive technology can help us achieve this; (iii) due to their cognitive complexity, captive elephants are a suitable target for such interventions. Our interest in this topic gave rise to our initial research question:

1. Will captive elephants engage with playful technologies designed to enrich their daily experience?

To answer this question, we needed to design, develop and test a playful interactive system that an elephant could use and that enriched her environment. Because environmental enrichment aims to encourage species-appropriate behaviours across a range of categories, such a system would have to offer a captive elephant an experience that reproduced some features of an experience enjoyed by a wild elephant, or which enabled the captive elephant to practice some of the skills that a wild elephant would naturally deploy.

Our research has explored the design of such systems, with the goal of creating an object that could offer elephants the opportunity to engage in playful interactions and perceive different auditory outputs, by allowing them to make choices and exercise control over their experience. Playful behaviour is seen as an indicator of good welfare in captivity (Young, 2003) and is therefore actively encouraged by the inclusion of toys into animal enclosures. Indeed, the British Elephant Welfare Group (EWG, 2020) endorses the idea that captive elephants should be provided with substantial enrichment, including toys. Moreover, an *interactive* toy could invite repeated engagement; learning how to use the device would be cognitively stimulating; the opportunity to control the output of the device would offer some variety, and acoustic enrichment is an underexplored topic in the context of enrichment for elephants.

There has been a significant amount of ACI research involving dogs as participants and/or target users of interactive technology, but fewer studies with other, non-domesticated animals, meaning that working with elephants allowed a fresh perspective to be explored. Moreover, as we shall see, many of the insights gained from working with elephants have resonance within other communities of users.

1.2 Overview of Research

Elephants pose an interesting challenge from the perspective of interaction design, because they perceive and interact with the world very differently from humans. This means that the design of any system that requires an 'elephant interface' needs to take account of their unique characteristics and preferred interaction modalities. An elephant's primary tool for interacting with the world is its amazingly strong and versatile trunk, which also has olfactory capabilities and is used for auditory signalling. That is very different from a pair of human hands, nose and mouth and therefore requires a novel and well-considered interface design. Humans have fingers and opposable thumbs; elephants have trunks with sensitive tips. Humans usually rely mostly on bifocal vision to perceive and navigate the world, whereas elephants' dominant sense is their phenomenal olfactory ability.

The field of User Experience (UX) design was energized by the need to design accessible, usable and enjoyable interfaces for a range of capabilities, functions and contexts, while recent developments in technology have enabled new kinds of interfaces to emerge. However, the starting point for designers of any new system remains the same as it has always been – understand the users and their requirements. As Sharp et al. (2019) explain, this is an important first step so that a brief can be agreed between the designer and their client, and so that the design is fit for purpose.

The first part of our research investigated this issue by reviewing current literature on elephant lifestyle, communication (preferred modes of interaction) and dexterity (physical abilities), in order to understand what might be feasible for an elephant with regard to using controls and receiving feedback from a device. As a result, we began to appreciate what elephants are capable of doing and were able to start addressing our second and third research questions:

2. **What playful technologies would elephants engage with, and how could these systems be designed to enable elephants to interact with them?**

3. What design methodologies would best enable designers to identify and develop the most appropriate designs for such technologies?

Over several years, we adapted research methodologies developed by the Product Design, Game Design, User Experience Design and ACI communities, starting by having discussions with animal welfare and behaviour experts. Computer scientists working with animals need professional people who can advise, offer suggestions, support our work and facilitate networking. Therefore, we identified a clear need to include animal experts in any practical project that involved animals, in order to give it legitimacy and proper grounding in the animals' needs and wants. In fact, collaboration with animal welfare experts and elephant keepers (as well as elephants) has been a key aspect of all our work, contributing to concept development and validation for design solutions. In particular, we are indebted to the keepers who supported our endeavours by providing rich feedback on elephant behaviour while we were testing our prototypes. At the same time, we undertook extensive research into the lifestyle of elephants, by conducting an ethnographic study of captive elephants in 2014 and comparing wild elephant behaviour with behaviour observed in their captive counterparts. This led to the identification of a series of behavioural goals – goals for enrichment based on some of the gaps in the experience of captive animals.

As we have mentioned earlier, elephants listen carefully and interpret the sounds made by other elephants, as well as responding to calls and adding their own comments. While it would be impossible to form herds where there are none, technology affords the possibility of adding novel acoustic devices to the environment in order to offer some of the cognitive and auditory stimulation that being part of a herd would naturally provide. The research therefore developed in this direction, mapping our idea of creating interactive toys to more clearly defined enrichment goals associated with communication. These goals included *listening* and *discerning, making meaningful decisions* and *enacting* those decisions by using technology-enabled devices. These goals provided the basis for design briefs that invited a range of possible solutions.

We subsequently began making progress with ideation and production workshops, taking a *Research through Design and Craft* approach. Initially, we approached the design challenge at hand from two complementary perspectives: (i) designing and crafting suitable interfaces; (ii) investigating appropriate outputs for an interactive system. The nature of the project meant that *Research through Design* (RtD) was highly relevant as a structured approach for developing a future end-product from an evolving concept, emphasising the need to underpin conceptual work with clear design goals relating to the theoretical and physical properties of the system – how it supported its purpose and how it manifested in the environment (Hengeveld et al., 2016; Lim et al., 2008). RtD allowed us to explore the problem space by progressively gaining insights through the making of successive prototypes, so that knowledge was gained during the process of designing. The *crafting* aspect of our work proved to be a critical activity that gave us multiple insights regarding the functional and aesthetic dimensions of the systems we were making. Meanwhile, *user-testing* the prototypes with elephants (and their keepers) was invaluable for gaining knowledge about individual preferences regarding modes of interaction and types of feedback. Our main elephant user was Valli, an Asian female housed at Skanda Vale Ashram, a sanctuary in Wales. We also tested prototypes with her companion, Lakshmi, another (blind) Asian female, and with Janu and Machanga, two African males at Noah's Ark Zoo in south-west England.

We began by designing and crafting a series of 'buttons' – digital interfaces that offered simple on/off states and that controlled either a water supply or an acoustic output. We installed multiple iterations of button designs in the elephant enclosure over several years, giving us the opportunity to experiment with different technical solutions and physical properties. These included, for example, buttons with knitted textile interfaces and buttons with embedded vibro-motors that offered haptic feedback. Our observations provided insights for the subsequent prototypes, which we have documented in a series of annotated graphical workbooks.

Consideration of the aesthetic aspects of the experience for the elephants became a paramount concern while we were focusing on the digital input devices. It became clear that the tactile quality of the interfaces held the Asian female elephant's interest, no doubt supplemented by olfactory phenomena that we could not appreciate. We realised that, as well as a binary on/off control, we needed to design an analogue control to capture elephant trunk tip movements and provide a graduated response – this was particularly important for acoustic output, so the elephants would be able to express preferences across a spectrum of acoustic variability – for example, controlling graduated volume or pitch.

We tested the elephants' interest in novel moving installations by suspending thick ropes from the rafters of their barn at Skanda Vale. Both resident elephants Valli and Lakshmi interacted with these ropes, but we realised that capturing the details of trunk movements using simple sensors embedded in the ropes would be difficult within our timeframe. We therefore decided to develop a system with limited linear movement, based on a slider, the kind of device humans often use in the context of DAWs (Digital Audio Workstations) in order to control sound effects, such as volume and pitch. The final version was developed with technical support from London Metropolitan University Art & Architecture Works (a specialist resource for rapid prototyping), and we are pleased to report that our elephant participants at Skanda Vale seemed to find it an engaging toy, continuing to interact with it over several weeks.

1.3 Outline of Thesis

In the following chapters, we document the progress of our work:

Chapter 2: Background Research

We have undertaken a literature review covering relevant themes: 2.1 Animal Welfare and Technology; 2.2 Design Methodologies in ACI; 2.3 Game and Design Methodologies; 2.4 Aesthetics.

In *2.1 Animal Welfare and Technology*, we discuss animal welfare and environmental enrichment, pointing out how technology has been used to facilitate the development of systems that offer a degree of control to their users. We consider the value of playful systems for offering cognitive and sensory enrichment, as well as observing how a technological device has potential to bridge the gap between users who are different species.

We then review some of the methods used in ACI research, in *2.2 Design Methodologies in ACI*, finding unequivocal agreement on the need to understand non-human animal users on different levels as part of the researchers' methodological approach. This leads to a discussion of how various ACI researchers have attempted to understand their users, by working with animals and by trying to imagine animals' perspectives on designs.

We subsequently consider methods used in the gaming and design communities, focusing on Game Design and Research through Design (RtD), as described in *2.3 Game and Design Methodologies*. The emphasis on both form and function in RtD motivates our final section *2.4 Aesthetics*, where we provide an overview of aesthetics as a cultural and as a multi-dimensional experience.

Chapter 3: Methodology

This chapter explains in detail the approaches taken in order to address the research questions, covering these aspects: 3.1 Understanding Elephants; 3.2 Elephant Requirements; 3.3 Concept Development; 3.4 Insights and Analysis.

In *3.1 Understanding Elephants*, we discuss the methods we used in order to try and appreciate the perspective of our elephant users, focusing on our relationships with animal experts and our independent research and fieldwork. We then explain how we attempted to interpret elephant requirements in a captive setting, in section *3.2 Elephant Requirements*.

The next section, *3.3 Concept Development*, elaborates on the ZooJam method we devised for initial ideation within a team setting and explains how we adapted RtD into Research through Design and Craft in order to fully realise our concepts and obtain feedback from elephant users. In the final section, *3.4 Insights and Analysis*, we provide an overview of methods used to analyse our work as it progressed.

Chapter 4: Understanding Elephants

There are two main sections in this chapter: 4.1 Understanding elephants as a species; 4.2 Understanding Elephants in Captivity.

4.1 Understanding Elephants as a Species is a summary of elephant lifestyle, cognition and communication, drawing on existing literature as well as discussions with experts in the field of animal behavior. This research was undertaken in order to compile criteria for a requirements specification, with a view to identifying ideas for playful systems that elephants might find stimulating. Elephant communication was investigated in depth to tackle the problem of developing an elephant-friendly interface.

4.2 Understanding Elephants in Captivity documents practical work undertaken from 2013-2015 at Colchester Zoo, Howletts Wild Animal Park, Skanda Vale Ashram, Blair Drummond Safari Park, Dublin Zoo and Noah's Ark Zoo in order to identify elephant requirements and investigate possible enrichment designs.

Chapter 5: Design and Craft

This chapter presents the design and development process, covering: 5.1 Enrichment goals and concept development; 5.2 Elephant requirements; 5.3 Workbook: Ideation and Production; 5.4 Inputs and Outputs; 5.5 Workbook: Input; 5.6 Workbook: Output; 5.7 Summary.

In these sections, we explain how we identified suitable enrichment goals, and how we investigated what might motivate an elephant to engage with a high-tech system that delivered these goals. We then describe our fieldwork as we explored the physical properties of such a system. The annotated workbooks showcase our development work visually with detailed comments and collections of insights derived with each iteration of the designs.

Chapter 6: Reflections on Design and Craft

In this chapter, we reflect on the insights gained during the design and crafting process, focusing in particular on these areas: 6.1 Participatory Design with Humans; 6.2 Interaction Design for Elephants; 6.3 Craft as Mediation. We finish the chapter with a section on: 6.4 Ethical Reflections.

The first section, *6.1 Participatory Design with Humans*, considers our collaborations with humans, including animal, technical and academic experts, as well as the development of the ZooJam workshops, which provided opportunities for interdisciplinary collaborative design and skills sharing.

We then reflect in detail on our experiences in the field, designing and crafting devices for elephants that we installed in the animals' environment. In the second section, *6.2 Interaction Design for Elephants*, we explain key design features and elaborate on our aesthetic contributions to the field of interaction design for animals.

The penultimate section, *6.3 Craft as Mediation*, explores the value of craft as part of a methodological approach to an ACI design challenge. We explain how craft enables ACI designers to become more aware of the sensory aspects of designed objects and how a crafted object mediates between the designer and the animal user; moreover, we show how co-crafting can support collaboration within a team of human developers.

Finally, in *6.4 Ethical Reflections*, we contemplate some of the ethical considerations associated with this field of research.

Chapter 7: Contributions

This chapter presents five key contributions arising from the project: (i) a methodology, *Research through Design and Craft*; (ii) a kind of workshop, the *ZooJam*; (iii) three principles of interaction design; (iv) research into *More than Human Aesthetics*; (v) a deck of *Concept Craft Cards*. The final contribution is a work-in-progress, whereby we present our work as a deck of cards aimed at developers of systems for animals.

Chapter 8: Future Research

Here we collect and present the many questions that have arisen during our research with elephants – questions we have been unable to tackle, because they were outside the scope of the project. We share them in the hope that other researchers may find them worthy of investigation.

References

Appendices

This section comprises:

(i) Ethics forms submitted to various institutions – Woburn Safari Park, Colchester Zoo, Blair Drummond Safari Park, The Open University.

(ii) Professional Development – courses taken at the Open University and externally.

(iii) Meetings with Experts – Elephant Welfare Group 2013.

(iv) Colchester Questions for Keepers 2014 – short reported interview with Head Elephant Keeper.

(v) Summary of SHAPE Environmental Enrichment Course (SEEC) 2014.

(vi) Ethnographic Data 2014 – snapshot of notes taken during observations at Colchester Zoo and an overview of elephant behaviours.

(vii) Media links – *toys4elephants* blog + Vimeo *UX for Elephants* video showcase.

Background Research

Underpinning our work is an extensive literature review covering various relevant themes. This chapter describes the background research undertaken prior to taking the decision to focus on elephants as potential users.

We start with an overview of Animal Welfare and Technology, taking into consideration environmental enrichment, offering environmental control, playful systems and inter-species interactions. We then describe how technology has been used with animals in recent times, moving on to a review of how ACI researchers and practitioners in particular have tackled this challenge, focusing on various methodological approaches. We then consider some alternative methodologies that may serve our purpose, drawing on work from Design Research and Game Design.

Sections

1. Animal Welfare and Technology
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2.1 Animal Welfare and Technology

Attitudes to animals and their welfare have varied across cultures and over time. In the pre-historic world, all animals were wild and free. Humans hunted them for food (Young, 2003) and often involved them in mystical rites (Foer, 2010). As numbers of humans grew and early settlements were established about 16,000 years ago, the first livestock farmers began to domesticate some species, making them easier to manage. Evidence indicates that dogs were first (Bradshaw, 2012), followed by farm animals (chickens, sheep, goats, pigs, cattle), and then from 8500-1000 BCE, cats, horses, donkeys, camels, silkworms, bees, ducks and reindeer (Hirst, 2019). The first known collections of wild animals, in menageries (kept captive as status symbols), are attributed to the Egyptians, around 3000 BC (Rose, 2009).

Managing animals raises the issue of caring for their welfare. Philosophical arguments against using animals purely for human benefit appeared around 3000 years ago in early eastern religious (Jain, Hindu, Buddhist) texts advocating 'ahisma' - non-violence to all living creatures (Ananda.org). In the West, vegetarianism was seriously considered by Greco-Roman philosophers (Morgan, Brittanica.com) around 500 BCE, and animal rights were advocated for during the Enlightenment (18th century) by writers such as Rousseau and Voltaire, in a refutation of Descartes' position – which was that they were insentient automatons provided for us by God (Giraud, 1985). In the UK, the first serious (documented and political) debate regarding animal welfare was ignited in 1798 by Jeremy Bentham, who is quoted as saying: '*The question is not can they reason? Nor, can they talk? But can they suffer?*' The implication was that animals can indeed suffer and that humans should therefore aim to reduce their suffering.

Bentham's comments were expressed in the context of an anthropocentric Western European society that widely viewed the rest of the animal kingdom as beasts whose divine purpose was to serve humans, part of the Descartes legacy (Thomas, 1984). However, in the following century, attitudes gradually began to change. Battersea Dogs Home (for stray dogs) was founded in 1860 (battersea.org.uk) and both the Government and the public became aware of brutal acts being performed on animals in the name of science. This resulted in the Cruelty to Animals Act being passed in 1876, (web.archive.org) in an attempt to control the practice of vivisection by eager researchers who regularly dissected live animals, such as cats and dogs, without giving them adequate (or any) anaesthesia. Fourteen years after this, Henry Salt wrote the first book devoted to animal rights (Salt, 1892) as well as producing work that advocated vegetarianism and discussed early environmental issues (Salt, 1926). The practice of vivisection continued to ignite strong feelings between those opposed to it and those fascinated by it, with experimentation on animals still being contentious in the 21st Century.

The implications of the prevalent attitude towards using animals to meet human needs became far-reaching during the 20th century with the massive increase in intensive farming – an industry that continues to grow today. Intensive farming aimed to optimise production for a rising population, by reducing the cost of animal products and the time taken for a product to reach maturity. This was enabled by advances in technology, such as genetic engineering, dietary supplements and industrialised breeding and processing plants. Unfortunately for the animals concerned, there were negative consequences to these procedures, which eventually provoked further demands for animal welfare to be taken seriously.

A highly influential book was published in 1964 by Ruth Harrison – '*Animal Machines'* – which was critical of contemporary husbandry and exposed factory (intensive) farming methods to public scrutiny. A government investigation (the Bramble Report, 1965) into the claims in Harrison's book led to the recommendation for five freedoms for farm animals (to stand up, lie down, turn around, groom themselves and stretch their limbs). This led to The Farm Animal Welfare Advisory Committee (later FAWC) being established. In 1975, Peter Singer, having read Harrison's book, published '*Animal Liberation'* (Singer & Harari, 2015), which built on Bentham's sentiments and became a highly motivating text for activists. By 1979, FAWC had clarified the following *Five Freedoms* to which farm animals were entitled (as mentioned in *Chapter 1: Introduction*):

1. from hunger and thirst
2. from pain, injury and disease
3. from fear and distress
4. from discomfort
5. to display normal behaviours.

The first four freedoms mention negative experiences to be avoided, but the fifth freedom recognises the idea that animal welfare is tied to the animal being able to behave naturally, not only to remain physically healthy. This is the aspect we focus on in our research, exploring different methods for allowing captive animals to experience some natural behaviours.

Following this, in 1994, Mellor and Reid proposed a new model – the *Five Domains* – whereby each of the freedoms were mapped to specific '*domains of potential compromise*', namely: (i) Nutrition; (ii) Health; (iii) Mental State; (iv) Environment; (v) Behaviour. This model emphasised that minimizing negative states is not sufficient for providing positive welfare and focused on the *mental state* of an animal, stating that each state had a demonstrable impact on an animal's overall mental wellbeing. Thus, there is a strong connection between *physical* welfare and *emotional* welfare.

FAWC subsequently outlined minimum standards of animal welfare and introduced the idea of quality of life for animals: '…*a "life worth living" from (the animal's) point of view and (the idea) that an increasing number should have a "good life"*' (FAWC Report, 2009). The RSPCA (rspca.org.au) elaborates thus: '*To help ensure animals have a "life worth living" they must have the opportunity to have positive experiences, such as anticipation, satisfaction and satiation*.' This research directly contributes towards achieving these aims.

The contemporary welfare point of view (*Appendix 2: Professional Development - Animal Welfare and Behaviour Course, 2014*) is that the same conditions of welfare apply to all members of a species, whether domesticated (pets, stray, farmed, laboratory) or wild (in zoos, sanctuaries and labs or living freely as part of the natural world). It should be noted that there is another school of thought, focused not on welfare but rather on animal rights, and specifically seeking to prevent human exploitation of animals, whether as companions, livestock, entertainment or experimentation. People for the Ethical Treatment of Animals (peta.org), for example, state explicitly '*Animals are not ours'*; they investigate and highlight acts of cruelty to animals around the globe while promoting a vegan lifestyle.

Animals kept in zoos and sanctuaries fall into the 'wild' category, because they have not been domesticated and they are being maintained as representatives of their wild counterparts. However, these captive animals may face a number of welfare challenges, including lack of exercise and stimulation, due to space restrictions, limited numbers of conspecifics and the ready availability of food (Young, 2003). In general, captive animals are not required to use their brains to full capacity, which can lead to a range of psychological and physiological problems, such as boredom and associated stress.

Maegher and Mason (2012), in relation to captive mink, comment: '*The situation of prisoners serving life sentences probably best parallels the one faced by captive animals; neither prisoners nor animals are deprived of all stimuli, but they do face a very unchanging, inescapable environment, which induces boredom in the humans.*' They explore the link between boredom, apathy and depression and exposure to uncontrollable stressful events, in their discussion of boredom in mink. Core symptoms of depression include anhedonia, which is a reduced capacity to experience pleasure, typically measured in terms of the decreased consumption of rewards. Apathy is marked by a state of generally reduced motivation or participation in activities. When the authors tested captive mink by giving them treats, all the mink showed interest, which is consistent with boredom, rather than depression or apathy, highlighting that the animals were craving new stimuli.

Animals in laboratories are usually domesticated species or have been chosen partly because they are easy for humans to handle. Nevertheless, their captive environment means that they are subject to similar welfare problems. The Animals (Scientific Procedures) Act 1986 established a set of principles underpinning the humane use of animals in research. It is known as the 3 Rs, originally proposed in '*The principles of humane experimental technique*' by Russell and Burch in 1959. The 2012 Amendments to the ASPA, following the European Directive of 2010 on the protection of animals used in research, further insist on the 3 Rs principles. Essentially, these are to:

1. **Replace** the use of animals with alternative techniques that do not require the use of animals or replace with a less sentient species.
2. **Reduce** the number of animals used to a minimum to achieve statistical power.
3. **Refine** the way experiments are carried out, to make sure animals suffer as little as possible. Importantly, as well as improvements to procedures in order to minimise pain and suffering, refinement also includes the improvement of housing conditions, namely through the provision of environmental enrichment.

The introduction of environmental enrichment into animal enclosures as a way of improving welfare has now also become commonplace for animals living in zoos and aquariums. Indeed, the Association for Zoos and Aquariums (AZA) publishes clear guidelines that focus on environmental enrichment for animal welfare. '*Enrichment is a dynamic process for enhancing animal environments within the context of the animals' behavioural biology and natural history. Environmental changes are made with the goal of increasing the animals' behavioural choices and drawing out their species-appropriate behaviours, thus enhancing animal welfare*.' (1999 AZA Behaviour Scientific Advisory Group)

2.2 Environmental enrichment

If a zoo has a conservation programme, aimed at releasing captive-bred animals back into the wild, it has a specific duty to maintain those individuals' behavioural competences so that they are able to function successfully when they are freed (Young, 2003, p.27). There is also an educational benefit to the public if zoo animals are behaving naturally, which is likely to enhance the reputation of the establishment. Additional support for the need for enrichment is offered by Robert Young (2003), who emphasises that it provides benefits to both the animals and their care givers, empowering both parties.

Young (2003, p.44) explains that the provision of enrichment improves animal welfare in two ways - it empowers an animal by allowing it to express control over its environment and it reduces the animal's level of fear by giving it appropriate stimulation. These factors help meet the goals of animal welfare – to maintain the animal in good physical and psychological health. Similarly, delivering enrichment to a species has potential for empowering the caregiver, by providing opportunities to research, design and evaluate the interventions, thus fostering a positive attitude in the humans whose responsibility it is to offer care. As a case in point, Young cites Hemsworth and Gonyou (1997), who found that equine stock-hands (workers who handle the livestock – in this case, the people who ride, herd and otherwise manage the horses) were more likely to react in a positive and predictable way with their animals if they (the stock-hands) were happy.

Given that enrichment seems to have positive effects on both animals and their keepers, the question arises as to what kind of enrichment we should offer a captive animal, in order to empower the animal and provide appropriate stimulation. The answer to this depends on the individual species and the situation in which it finds itself.

There are different categories of environmental enrichment, relating to food provision as well as sensory, social, environmental and cognitive experience (SEEC, 2014). Feeding-related enrichment is now common-place in UK zoos. As well as offering a nutritional reward, scattering food and using puzzle feeders stimulates physical activity that exercises the body and poses cognitive challenges that exercise the mind. Additionally, this kind of enrichment is an interesting way to expend time in an enclosed space where there are limited opportunities for stimulation; indeed, it is well known that many animals prefer to work for their food (known as contra-freeloading - Osborne, 1977; Podelsnik & Jimenez-Gomez, 2016; Washburn & Rumbaugh, 1992).

However, feeding is only one aspect of a captive animal's life experience, even if it occupies a significant portion of their time. Mills et al. (2012) describe how a captive animal whose basic (physiological, safety-related, social) needs are met is still driven to seek cognitive stimulation and needs novel challenges to overcome. In the wild, an animal has complete autonomy and can make meaningful choices in a complex living environment; in contrast, captive animals lack control over many aspects of their lives, where routines are imposed on them for practical reasons and social dynamics are often compromised by enforced proximity to, or separation from, conspecifics.

Within the confines of a zoo, there will inevitably be limitations to the kinds of enrichment that can be delivered. For example, changes to the physical habitat of a species may be constrained by the budget of the zoo and the space afforded by the enclosure, while social aspects will be dependent on the numbers, ages and genders of conspecifics held captive. In addition, zoo animals are typically subject to a strict routine, imposed by staff out of necessity so that daily tasks can be accomplished at set times. This is also important for welfare, as routines help reduce the unpredictability of events, which is known to cause animals stress (Basset and Buchanan-Smith, 2007; Mancini et al, 2014). The combination of practical constraints and limitations imposed by routines in a captive setting means that, overall, the animals kept there do not have many opportunities to make relevant choices – for example, with regard to their environment, companions, schedule, diet or exercise.

Although current environmental enrichment can go some way towards enhancing an animal's welfare, it is not possible to replicate for captive animals the actual experience of living in the wild. As mentioned above, captive animals do not have so many opportunities to make selections; they lack control over many aspects of their environment; social dynamics are often compromised by enforced proximity or reduced numbers of conspecifics. However, it is possible that technology could help mitigate some of these challenges, albeit in an "artificial" way. One of the themes of this research has been the idea that technology can enable animals to exert more control over their environment, which in turn may lead to reduced levels of stress and higher welfare.

2.2.1 Offering environmental control

Welfare experts have endorsed the idea of offering animals more control over aspects of the captive environment (Mills et al, 2012; Whitham & Wielebnowski, 2013; Young, 2003, Coe 2017). In particular, Mills et al. (2012) explain why control is important in the context of homeostasis, whereby an animal is driven to respond to changes in her environment in order to reduce stress and maintain an optimal physiological or social condition. The ability to control something is an opportunity to respond to a stimulus, requiring the exertion of both physical and mental skills that animals have evolved to express. As a case in point, Buchanan-Smith and Badihi (2012) explored the idea that having control is enriching in a series of studies with captive marmosets during which some of them were provided with switches they could activate in order to increase the amount of light, and simultaneously the amount of heat, in their cages. A decrease in the behaviours that were being used as indicators of reduced welfare, such as the amount of time spent self-scratching and scent-marking, suggested that the animals given controls to use were less stressed. In an earlier experiment, Washburn et al. (1991) confirmed that rhesus macaques were able to exercise choice using a screen interface and moreover that they performed better in tasks they had chosen to do using this selection procedure than in tasks assigned to them by a keeper. The authors suggest that this shows the potential for offering choice and control as part of an enrichment programme. In support of this, Coe (2017) has proposed *Five New Freedoms* – the 5Cs – in relation to environmental enrichment initiatives. These are *choice, control, challenge, change* and *competence*.

In contrast to this, Jones and Nicol (1998) found that providing pigs with operant controls over a source of infrared heating had few discernable welfare benefits. Their research does not mention how often the pigs used the control to increase the temperature, but states that the pigs who had the controls spent significantly more time lying huddled together than the pigs who had a consistently warmer environment. The authors suggest that the age at which the animals are introduced to the concept of having control might be a critical factor. Taylor et al. (2001) tested a feeding and lighting system with hens, using a peck-activated key to release the lid on a feeding tray for 30 seconds. All hens also had an open-access time when grain was freely available. Not all hens reacted in the same way; some contra-freeloading took place, with certain hens clearly preferring to work for their grain. With regard to welfare, the only significant differences between groups of hens were reduced egg production from the hens that had access to the controls, the reasons for which were not clear to the authors.

The designs of the controlling mechanisms are mentioned briefly in these papers and have been given some thought by the researchers, but not described in detail – for example, the marmoset buttons (from the Buchanan-Smith and Badihi study) had embedded lights to provide additional feedback indicating whether or not they had been activated; the pig control was a beam breaker that could be nose-activated, because this had previously been more successful than a push-button; all hens were given training with the peck-activated key and all were capable of using it. It is perhaps notable that the hens behaved differently in the same situation, so there was no universal response. Consideration of the individuality of the user is an under-explored aspect of system design (for animals) which has been given some thought in recent ACI work. An example is the study by Mancini et al. (2014) of dog kennels at Dogs Trust's Loughborough Rehoming Centre. This research investigated the potential for designing a responsive environment with smart controls that dogs could use for customisation, potentially providing them with cognitive enrichment and associated improved welfare. One of the factors emerging from the research was the observation that not all members of a species are identical, yet captive environments typically impose standardised experiences for their animals. There may be many good reasons for this, such as effective timetabling and management of personnel, as well as a degree of equality for the animals in confinement. As the Dogs Trust dogs are usually housed in pairs, they have company. The authors acknowledged that competitive behaviour might be exacerbated by the introduction of a novel mechanism for controlling aspects of the environment, as well as highlighting the possible negative repercussions for the animals' carers. None-the-less, there was a possibility that provision of control might also offer some personalisation of the captive animal's experience.

For animals housed individually, this idea seems practical, but for shared housing environments, there are challenges inherent in the design of a system that offers a personalised experience to one animal without imposing their choices on the other animals. This is one of the areas that will need careful consideration in this work, depending on the context of the animals using the system.

2.2.2 Playful systems

Several researchers have explored how animals might exercise control by allowing them to make choices in a playful context and their studies hold some insights for future development of technology-enhanced enrichment systems.

We humans have come to rely on technology to provide us with much of our modern stimulation. Living in urban environments with limited freedom and space, but arguably with more recreational time than our ancestors, we have adapted to use digital forms of entertainment in addition to our traditional cultural forms of storytelling, sports, music, dance, art and playing games. Steven Poole, who was born in 1972, comments: '*For most of my generation... videogames are just part of the cultural furniture*.' (2000) The relatively recent (since the first consoles were released in the 1980s) global enthusiasm for playing computer games is of particular significance in this research. Computer games, perhaps more than any other cultural phenomena, embody the idea of being an *active participant* who has some *control over their experience* in a *stimulating and cognitively challenging environment* – these are the same attributes that are said to enrich animals' lives and increase their welfare (Young, 2003).

There is a widely held view that human interest in playing games is associated with our cognitive development and ability to perform in more critical situations. For example, in the field of game design, Koster (2005) describes games as 'brain exercises', citing dynamics that mimic real-world challenges; Schell (2008) uses the framework of mental modelling to explain gameplay and its relationship with reality. For humans, game dynamics include collecting, chasing and evading, trading, cooperating, puzzle-solving, territorial acquisition, prediction, spatial reasoning (Braithewaite & Schrieber, 2009); we notice that all these activities also have relevance for other species.

If we accept that games give us opportunities to stimulate our brains in ways that may ultimately enhance our survival, there is every reason to suppose that playful activities might similarly augment the cognitive well-being and health of other animals.

Indeed, the expression of playful behaviour is recognised as a highly positive behaviour in captive animals (Oliveira et al., 2010). Burghardt's surplus resource theory (2005) claims that four factors need to be present for play to emerge – (i) animals should have sufficient energy; (ii) they must be buffered from stress or danger; (iii) they must be in need of stimulation; (iv) the species' lifestyle should be sufficiently complex. Zoo-housed animals tend to meet these factors well, as they are properly fed, kept free from danger, have time to be filled and many are species that would have a complex lifestyle in the wild.

Although it is relatively easy to identify, play is challenging to define because it is fluid and transient with no immediately obvious cause (Bekoff & Byers,1998; Sendova-Franks & Scott, 2012). None-the-less, researchers (Brown & Vaughan, 2010; Sicart, 2014; Burghardt, 2005) have attempted to characterise play, with the following attributes being commonly agreed: it is autotelic (offers intrinsic reward) and it is apparently non-functional (not directly related to fitness). However, there are a number of possible reasons for play behaviour, with some research favouring the idea that play prepares animals for their future lives by refining the control that the prefrontal cortex has over other parts of the brain, allowing the animal to become more adaptable (Pellis, Pellis, & Bell, 2010). Burghardt (2010) suggests that behavioural play is a precursor to mental play and may be an important factor in the evolution of cognitive and social abilities in different species.

There are three recognised types of play behaviour in non-human animals - social play, locomotor play and object play (Burghardt in Bekoff & Byers, 1998), described below.

- **Social play** - Bekoff's observations (2002) of pack animals (in particular, dogs) have led him to conclude that playing is an integral part of learning how to interact and flourish in a social environment. He suggests that a sense of morality has evolved through social play, because players have to understand the rules of engagement and not transgress the boundaries of acceptable behaviour, in order not to be excluded.
- **Locomotor play** - Locomotor play involves exaggerated physical activities such as running and jumping. Oliveira et al. (2010) point out that, while the precise reasons for this kind of behaviour are not clear, there seem to be no significant costs (when the animal is well-fed) and benefits might include improved physical development.

- **Object play** - Spinka et al. (2001) claim that toys are intrinsically cognitively enriching because any novel objects of interest – for example, new play equipment or furniture for enclosures – provide animals with “training for the unexpected”, a skill that would develop naturally in the wild, but which is likely to be under-developed in captivity where the living environment is much simpler and routines are in place.

Young (2003) points out that toys have been successfully introduced into animals’ enclosures in order to stimulate play behaviour for several years and that particularly ‘*mammal and bird species can benefit from the effects of toys*’ (p.149). On the other hand, Tarou and Bashaw (2007) propose that enrichment providing extrinsic reinforcement (such as food) is likely to have more long-term success in promoting behavioural change than intrinsically rewarding enrichment (such as toys). However, our research seeks to explore the design of autotelic experiences so that we might be able to determine some of the preferences of our users – this precludes the use of food, as many animals can be trained to perform activities with food rewards, whether they find the activities intrinsically enjoyable or not.

Traditional toys are designed for freeform play, in contrast to games, which have a formal structure and require players to understand and accept a system of rules, a distinction discussed by Callois (1961). It appears that animal play more closely resembles freeform play, which is spontaneous and improvisational, rooted in physical sensation and role-play (Brown, 2010). On the surface, toys might appear to offer fewer opportunities than games for exercising control and choice. However, recent developments have seen a new trend emerging towards ‘enhanced’ toys for captive animals (Westerlaken & Gualeni, 2016; Wirman, 2014; Gray et al., 2018), which include embedded technology and offer a measure of interactivity. The integration of a toy with a formal system imposes some game-like qualities on the experience in that the player needs to understand how the system works in order to be able to play with it, thus providing a cognitive challenge and promoting physical engagement and meaningful choices on the part of the animal.

Pigs were apparently early adopters of videogame technology, as evidenced by YouTube videos (youtube.com: Pigs Playing Video Games) showing a pig playing with a game in order to obtain treats, observed by swine researcher Stanley Curtis, who was investigating pig cognition in order to make recommendations regarding animal husbandry. Castello (in Lopez and Castello, 2008) says: ‘*Stanley Curtis found that pigs play and excel at joystick-controlled video games… they are capable of abstract representation and are able to hold an icon in mind and remember it at a later date… pigs communicate constantly with one another … more than 20 of their oinks, grunts and squeals have been identified in different situations such as wooing or expressing hunge*r.’ In this case, the pig

(Hamlet) was able to manipulate a ‘pig-sized’ joystick with his nose, receive feedback from the system via an animated display and be rewarded with food.

A different kind of playful pig project was undertaken by Dutch interaction designers in conjunction with pig farmers (Alfrink et al., 2012). The team used a computer game to improve farm animal welfare, as part of their “Playing with Pigs” project, aimed at reducing stress in barn-housed pigs. Lights on an interactive wall attracted the pigs’ attention and if they followed a light with their snout while a human simultaneously used an iPhone interface to follow the same light with a finger, the light would become brighter and make a colourful display. Although such technological interventions are not part of pigs’ natural experience, the pigs engaged with the installation. The Playing with Pigs project claimed to be successful both in entertaining pigs (thus reducing the incidence of tail biting behaviour) and in raising awareness of their existence and situation among the meat-eating public. However, while the game provided dual interfaces to the same application – one for pigs and another for humans – the humans understood that they were playing with pigs, but the pigs only played with the light spots.

Wirman (2014) designed a touch-screen game interface as part of the TOUCH project, whose objectives were to provide enrichment for captive orangutans, raise awareness of their well-being and facilitate cross-species communication (with humans). Talking about her experience, Wirman concluded that, while the orangutans were interested in the medium, their play was situated in a different context and that, ultimately, they failed to understand the game designs. She attempted to introduce them to “*games, videos, images, drawing software, music applications and digital cameras*” (2013), but the orangutans were much more focused on touching her skin, playing with her hands, pulling cables and doing other *physical* activities (rather than digital ones). Wirman subsequently affirmed (in Wire, 2013) that she hoped to follow up the TOUCH project with more game designs that targeted the interests of orangutans more directly, possibly using technology embedded into smart toys. Wirman’s insights highlight the need to keep the player at the heart of any user experience design.

Ritvo and Allison (2014) tested the effectiveness of musical acoustic stimulation to entertain orangutans. They drew similar conclusions to Hannah Wirman (TOUCH project) regarding the use of a touch-screen interface, determining that the orangutans struggled to use this interface. The authors concluded that this was because orangutans typically walk using their knuckles and keep their hands curled. Opening their fingers to interact with a touchscreen was unnatural for them, so they tended to use sticks as tools instead. Therefore, a touch interface was only successful if the screen was resistive, rather than capacitive, which relies on contact with a living creature. For this piece of research, there did not seem to be much thought into the quality of the sounds themselves – the orangutans could extend the time that they were played, but not exercise much control over the timbre or frequency.

Herzing et al. (2012) conducted a study of play behaviours in dolphins, using an underwater keyboard interface that could be used to produce referential signals. The keyboard used both acoustic and visual signals that labeled a set of familiar toys, enabling the dolphins to choose, and also to respond to requests made by humans. The authors hypothesized that: '… *a dolphin, through exposure to the modeled referential communication between humans, would learn that this type of communication can be used to achieve goals, and thus would spontaneously begin to use the system to request objects.*'

Other current playful systems for companion animals include iFetch (goifetch.com), which shoots out a ball for your dog to catch while you're away, and CleverPet (clever.pet), which dispenses treats when your dog solves progressively more difficult 'Simon Says'-type matching puzzles. This kind of technology and their design have become much more sophisticated over the last five years, and all the products purport to be aimed at improving the companion animal's welfare, many of them endorsed by veterinarians.

2.2.3 Interspecies playful interactions

One of the initial aims of this project was to explore ways of bridging the gap between diverse users and to provide a shared playing experience, using technology as a tool to support their cooperation and engagement.

Playing is a friendly form of engagement – a first step towards establishing trust between participants. Play can constitute a form of completely non-verbal communication and it can be the precursor to a deeper understanding of a co-player, potentially one of another species. John Bradshaw (2012, p.205) states: '*To be successful, play [with another] requires very well synchronised communication…*' Although this makes interspecies play a rare occurrence, his focus is on dogs, who love to play with humans. Dogs have evolved (been selected) to have most of their needs cared for by owners and to be willing to interact with people, which may be why they are often keen to play with humans.

'CAT' – Canine Amusement and Training – is a successful attempt by Wingrave et al. (2010) to use technology to enhance interactions between humans and dogs in a playful way. The authors' brief included designing a "serious" game that humans and dogs could play together, and which would facilitate owners being able to train their dogs and spend quality time with them. They used aspects of game design to enhance the experience for the players - such as unlocking new features gradually, based on success in addressing challenges, in order to scaffold the game process and ensure that the humans were not pushing their dogs too hard, too quickly. The game required the use of remote sensing technology (Wiimotes and IR transmitters) worn by the dogs, and visuals in dog-friendly colours projected onto the floor so that all players were aware of the game space.

Wirman's above-mentioned TOUCH Project used touch screens to facilitate inter-species gameplay between humans and orangutans. As a catalyst for playful interaction, the devices were successful because they promoted attention and interest between participants, despite not working in the way the researchers had anticipated. Similarly, the CHAT (Cetacean Hearing and Telemetry) system used by Herzing et al. (2012) was most successful when the human participants were paying a lot of attention to the dolphins, for example by holding eye contact. This device captured the acoustic signals made by dolphins and if a dolphin whistle matched a 'signal whistle' (previously linked to a specific toy), the name of the toy was played into human headphones, in effect translating the whistle for the human. This demonstrated that the dolphins had learned a new whistle and moreover, when it was used in conjunction with the correct toy, that the dolphins understood the whistle as an abstract signal representing a particular object. Humans were also able to use the system to reference particular toys acoustically, using a dolphin-friendly sound.

The Playing with Pigs project (Alfrink et al., 2012) was aimed at both pigs and humans. However, there was no opportunity for a shared experience, which was a deliberate design choice that respected the structure and management of the pig farm, where pigs have a place to live and interact with other pigs, not with humans. There have been other attempts to establish interactions between humans and other species remotely, using technology to bridge the physical gap. Resner (2001, Rover@Home), who developed a system for remote interaction between humans and dogs through species-specific interfaces, states: '*By studying and interacting with HCI in a new context [that includes dogs and humans], one can gain insight and inspiration about how to adapt computers for use by biological entities.*' His work aims to offer a degree of companionship to dogs left at home, allowing their owners to 'play' with them, but it also demonstrates how we need to explore different modalities in order to create interfaces for other animals. Lee and Cheok (2006, Poultry.internet) enabled remote interactions between humans and pet chickens using mixed modalities. Humans could watch and touch a 'chicken doll', and their interactions with the doll were transmitted to a live chicken via a haptic jacket won by the bird. The chickens' movements were simultaneously transmitted back to the human interface, whereby participants could see and feel the doll moving. The LionRover project (Jones et al, 2005) also utilized remote technology for a purpose directly connected with enrichment. It aimed to provide a realistic alternative to live prey for large felids at Blair Drummond Safari Park. Prototypes were developed around the concept of a remotely controlled device, manoeuvered by the keepers in an attempt to provide a continually unpredictable form of hunting enrichment. The results suggested that the LionRover was successful in promoting increased expression of natural behaviours in the pride.

Many of the early applications for remote interaction were very obviously human-centred, focusing on providing an interesting experience for people, rather than being aimed at improving the welfare of the animals on the other side. Launched in 2012, 'ipet companion' (ipetcompanion.com) enabled users to remotely interact with a cat-toy (e.g. a swinging tail) and make it move, while watching cats on a webcam to see how they responded. Although this might have been somewhat entertaining for the cats, the real purpose of the device was to attract potential supporters and customers to refuges and pet centres. By 2020, the same site has become a portal for various cat-related products – none of them purporting to enable remote interactions. Similarly, 'Live Diver', which was hosted at the Aquarium of Boise in 2015, allowed users to remotely steer a submerged webcam in order to view fish underwater for a limited time. The aquarium's online marketing campaign suggested that the designers envisaged the webcam would provide an exciting experience for viewers. In these early cases, the animals had no idea that they were 'playing' with anyone. For another example, Dublin Zoo is one of many establishments that have supported their educational programme by installing live webcams so that online visitors can see their animals in real time (dublinzoo.ie). This is a marketing strategy, aimed at encouraging more visitors; the animals have no awareness of the system.

More recently, Petcube Cam (petcube.com) states its mission to be: '*Connecting pets to the Internet and giving them a voice*.' The basic version is a webcam installed in the home that allows people to view their companion cats and dogs remotely; there are versions with laser pointers to excite cats and versions with two-way audio and treat dispensers for both cats and dogs – all remotely controlled via mobile phone. It is not clear how these devices 'give a voice' to the animals.

In addition to the remote viewing via webcams associated with these toys, tracking and telemetry are being used to connect humans with their companions, when they are not co-located. Tracking and telemetry have been common methods for capturing data about animals for many years. Movebank (movebank.org) is a free, public repository of animal tracking data, sharing information collected via GPS (Global Positioning System) tagging systems, PTTs (Platform Transmitter Terminals for satellite telemetry), radio transmitters, or geolocators. Each system has advantages and disadvantages relating to size and weight, battery life, whether data is actively tracked or passive (must pass by a sensor), is saved locally or transmitted via satellite. Recently, cheap lightweight equipment has made it feasible for members of the public to tag and track their companion animals. Mancini et al. (2012)

explored whether this new capability changed the relationship between owners and their pets (specifically dogs), focusing on both the human and animal experiences. One of the findings was that using a tracking device meant that humans allowed their dogs more freedom, because they felt confident about knowing the dog's location. While this raised questions about maintaining the balance of power between the owner and the pet, the anecdotal evidence seemed to be that the dogs looked forward to the experience of wearing the device, presumably because it predicated a long walk off-lead. Paci et al. (2019) investigated companion animal welfare in the context of wearable devices for cats, which can be used to track location, activity and fitness. These wearables are not marketed as playful products, but nevertheless contribute towards the goal of enhancing interspecies relations (in one direction only), by providing the human partner with data. Paci et al. developed a framework to support the design of such devices so that their impact on the wearer would be minimal.

While this kind of tracking is useful to mediate the connection between free-roaming animals and humans, equipping us with knowledge we would otherwise not have, it is less likely to be useful in a zoo or wildlife park setting, as the keepers can already see the locations of large animals such as elephants. None-the-less, tracking data remotely is a useful method for collecting information about system usage and monitoring how an animal interacts with a toy overnight, for example.

So far, we have discussed animal welfare and environmental enrichment, pointing out how technology has been used to facilitate the development of systems that offer a degree of control to their users. We have considered the value of playful systems for offering cognitive and sensory enrichment, but not yet considered the different methods that could be employed for designing such devices. In the following section, we discuss existing work within the ACI community.

2.3 Design Methodologies in ACI

In Interaction Design, the importance of user-centred design has been long established and interaction designers know how, in order for user-centred design to be possible, it is paramount that the user is involved in the design process (Sharp et al., 2019). By analogy, one of the key aims of Animal-Computer Interaction is the development of user-centred design methodologies that enable animals to be involved in the design process as active participants and design contributors (Mancini, 2011: ACI Manifesto). This presents obvious challenges due to interspecies differences and communication barriers, to address which ACI researchers have proposed a range of methodological approaches. We discuss a number of examples in the following sections: (i) Understanding users; (ii) Working with users; (iii) Imagining users.

2.3.1 Understanding users

In 2001, Resner took up the challenge of designing a computer mediated system enabling owners to remotely interact with their dogs – known as Rover@Home. He was interested in applying user-centred design principles to a system with asymmetric interfaces – one for the dog and another for the human. Resner is clear about situating HCI within the broader field of ACI, explaining how our knowledge of HCI is highly relevant and transferable "*because it deals with the adaptation of mechanized systems to biological systems*".

His approach was initially to consider how four aspects of HCI – task domains, affordances, cognitive modeling and direct manipulation – apply to non-human animals. He concluded that the task must be relevant for the animal, taking into consideration its natural behaviours; actions the animal is required to do should be similar to those it already performs, to take advantage of existing cognitive models; the interface should provide easy access to the task using affordances consistent with the animal's natural abilities (e.g. something the right size and shape for a dog to bite and pull) and that the interface should be as direct and literal as possible, facilitating clear mapping between actions and results.

Following this, Resner used the method of *contextual inquiry*, investigating his users in their natural environment in order to make sense of the issues related to the above-mentioned HCI aspects. Domesticated dogs were the focus of the study. In any case, he claimed that including the canine users as participants in the design process was impossible, because of the communication breakdown between the species (canine user and human designer). Ultimately, his design for the dog interface was heavily influenced by clicker-training learned behaviours (clickertraining.com) – the human uses voice commands to direct the dog to touch a target and if this happens successfully, remotely dispenses a treat. It is worth pointing out that his concept is not dissimilar to many of the products for sale in 2020 that we described earlier.

Techniques specifically for designing interactive toys for animals have recently been proposed by Pons et al. (2015) and Wirman and Zamansky (2016). Both emphasise the need to start by *investigating species-specific behaviour*.

To support the design and evaluation of technology for mediating human-animal interactions, Mancini et al. (2012) proposed *multispecies ethnography* as a way of understanding the design spaces when working with animals. They investigated the semiotics of exchanges of information between humans and their dogs when the owners were remotely tracking their pets, focusing on how the mediating technology might invoke new insights and meanings for each party. It was possible to ask the humans how they felt about the experience, and how they interpreted their dogs' reactions. The authors also proposed an 'interspecies semiotic model' for framing the responses of animals to technological interventions.

To address the problem of designing appropriate interfaces for Diabetes Alert dogs, Robinson et al. (2014) used a *multispecies ethnographic approach* to initially establish requirements. Diabetes Alert working dogs typically live together with their human handlers, indicating that both species need to be taken into consideration. The authors state that the individual characteristics of the users (dogs and humans), combined with the different circumstances of each human-dog partnership, suggested that *working together with users* to develop designs was more appropriate than attempting to design for them relying only on outsider observations and background research. This approach was a method for gaining deeper understanding of the dogs' characteristics and environment.

2.3.2 Working with users

Robinson et al. (2014) conducted intensive fieldwork with dogs and handlers in order to try and understand what kind of system would work best, with the stakeholders participating in the process. Their conclusions were that *rapid physical prototyping* is a good method for engaging both dogs and humans with a novel system and enabling a dialogue (about the design) to take place. Rapid physical prototyping involves making a succession of rough, low-fidelity prototypes that can be tried and changed quickly, thus keeping the stakeholders interested and giving them plenty of opportunities to offer suggestions and feedback. In this case, the point was also to maintain the dogs' interest, allowing them to demonstrate their preferences.

As we mentioned earlier, Lee et al. (2006) researched remote interactions by focusing on chickens and humans, and the provision of haptic interfaces. They reasoned that another's presence is more acutely felt through tactile stimulation, which provided the rationale for their design, intended initially to promote intimacy between office-bound humans and pet chickens, although the ultimate goal was to support a physical connection between parents temporarily separated from their children (‘*Internet pajama’*, Teh et al. 2009). Whereas Resner was concerned with the welfare (and good behaviour) of pets left alone by their human owners, Lee and colleagues point to a wider significance for their work, suggesting that: ‘*it paves the way for humans and animals to work together in a collaborative way based on equal partnership*’. The authors managed to overcome the problem of communicating with the animals about the designs, highlighted by Resner, by using *preference testing* with their chickens. The chickens could choose whether or not to engage with the system by accessing a space in which they had learnt they would be fitted with the vest and experience haptic feedback. In trials, 70% of them selected to enter the space, even when researchers made it increasingly harder to do so by placing a weight on the entry flap.

Ritvo and Allison (2014) discuss preference testing as part of their analysis of methods that can be used to assess usability and user experience from the perspective of non-human animals using technological artefacts. They point out that with compulsory paired choices (i.e. preference testing), whereby animals are forced to choose between two experimental conditions, animals may be selecting the least unpleasant option, rather than making a positive choice for an experience they enjoy. As a result, Ritvo and Allison suggest that participant-controlled procedures, which allow the subjects to choose whether or not to engage and for how long, may be a better measure of enjoyment. This is consistent with the idea of using as enrichment *playful technology* the animal can engage with at will, since one of the defining features of play is that it is a voluntary activity (Brown & Vaughan, 2010).

Some researchers value *participatory design* (PD) and believe it can be applied to designing systems for non-human animals, although questions arise regarding how we can obtain reliable feedback when all our perceptions (of animal responses) are filtered through our human experience. Lawson et al. (2016) are skeptical of the notion of PD with animals, based on studies conducted with dogs and their owners. They point out that the power balance is never shifted in favour of the dog and that animals’ lack of language means that they are unable to offer meaningful feedback on their experiences. Jorgensen and Wirman (2016) also highlight how difficult it is to understand an animal’s point of view, but offer a *play-oriented approach to PD*, whereby human designer and non-human animal user engage with each other in a playful scenario that aims to bridge the communication gap between the species. This method was appropriate in the context of captive orangutans, since the designers were trying to design a toy that enabled cross-species play.

Suggestions for how PD can be facilitated as part of a working relationship between species have also emerged. Mancini and Lehtonen (2018) propose a new model of participation that requires the animal to choose to take part and where both the human and animal partner can assess the other's perspective based on behavioural signals and semiotic associations meaningful to each in on ongoing process of negotiation. Ruge et al. (2018) have also undertaken research on the interpretation of tail-wagging in dogs, finding that these are not always easy-to-read indicators as they are personality-dependent.

Pons et al. (2015) and Zamansky and Wirman (2016) both recognize that the self-rewarding nature of *play* makes an *interactive toy* an ideal vehicle for exploring ACI. Zamansky and Wirman propose a *framework* derived from the loop of input and output that exists when an animal interacts playfully with a system. The framework offers a checklist of questions to be considered by designers, arranged in categories: Animal, Device and Environment. The authors' focus is on how technology can be used to create playful interactions.

In a similar vein, Westerlaken and Gualeni (2014) proposed a new evaluation methodology for ACI design, named '*digitally complemented zoomorphism*', which has a strong focus on playful interaction between designer and animal, with the following general design guidelines:

1. *the use of external stimuli in the form of technological artefacts to motivate the animal to play and engage in human-animal interaction in a research setting and on a voluntary basis.*
2. *the pursuit of a closer understanding of the animal, its behaviour and its intentions by 'going-along' in the embodied praxis of play with animals we share certain characteristics with, in life.*
3. the complementation of the above with the digital tracking and collation of metric and biometric data whereby we can receive more objective insights in the interaction with the artefact and the changes of the animals' bodily measurements during specific technically-mediated activities.

Westerlaken and Gualeni's methodology may have relevance when we consider ways for evaluating our playful systems. However, the general consensus amongst animal behaviourists seems to be that, with many zoo animals, including elephants, a shared human-animal game experience is not desirable, as it detracts from the 'wildness' of the animal's experience in captivity (EWG 2013). Keepers are often encouraged to pursue a *protected contact* relationship with their animals, although this does involve basic training using positive reinforcement so that the animals can be handled by vets and inspected on a regular basis.

2.3.3 Imagining users

When it is not possible to ask appropriate questions or reliably interpret signals, designers have sometimes temporarily ceased to engage directly with their users and conducted thought experiments in order to creatively move forward, imagining the animals with the future designs. For example, initially, Robinson et al. (2014) used *scenarios* to explain the context to the humans in the dog-human partnership and raise suitable questions. The scenario told the story of a typical situation when a particular (imaginary) dog and particular (imaginary) human had reason to interact using a designed artifact. Pons et al. (2015), whose work was mentioned earlier, envisaged an intelligent, reactive, playful environment that would adapt according to the emotional state of the animal, thereby enhancing welfare. Their work was presented as a future possibility grounded in existing work on play in animals and adaptable systems.

Some researchers (Lawson et al., 2016; North, 2017; Hook, 2019) have expressed their ideas as design fictions. *Design Fiction* has an important role in ACI because there are so many unknowns in this new field of research; it is not currently possible to ask non-human users what they would like in the way of technological intervention, so we can only imagine systems that might be suitable. The act of designing these imaginary systems opens up the research problem by raising questions and framing the research in a narrative that is easy for another human to understand.

Design Fiction is a concept coined by Sterling in 2005, established by Bleecker in 2009 and consolidated in a manifesto by Dunne and Raby in 2013. It is one methodology in a broader spectrum of creative endeavour looking to the future called *Speculative Design,* which covers not only future objects (which can potentially be created), but also future scenarios and ideas, taking inspiration from science fiction – for example, the Doggy Internet portal devised by Lawson et al. (2016). The Dog Internet project was purely speculative, using a designed artifact in a diorama for people to view in order to share an idea, whereas North (2017) and Hook (2019) have both used technology to create physical devices that aim to support humans in understanding the inner lives of horses: North developed robotic horse ears and documented his experience while wearing these to communicate (via the ears) to other horses; Hook created a mixed reality headset that allows users to see through 'equine eyes'. Both of these horse concepts emphasised the *simulated embodiment* of the other as a means to gain insight and understanding, and both relied on sophisticated technology with detailed craftwork.

The ACI research we have reviewed emphasises, without exception, the need to *understand non-human animal* users on different levels – physiological, behavioural, cognitive – as a part of the researchers' methodological approach. This knowledge is acquired as a result of conducting background research but may also be gained by using an *ethnographic approach* and *rapid prototyping* approach, and enhanced during the design and development process, if it is possible to *work with the users*. Leveraging *play* within interaction design has repeatedly been highlighted as a beneficial approach, while imagining future possibilities through *speculative design* has produced some interesting and provocative concepts.

While all these methods are appropriate for ACI work, our research into playful technologies for elephants required an approach that encompassed iterative design, since initially there was no clear idea of what the final device would be like – this was a topic to be explored. We were committed to making systems and testing them with captive elephants so that we could evaluate our designs through providing users with choices and agency. Given the *size and strength* of an elephant, and our vision of creating an *interactive* object, there had to be an emphasis on construction and embedded technology. We therefore looked to the design and gaming communities for some inspiration on suitable methods to use for ideation and development, since we needed to *design and make* an artifact, and we were interested in techniques used by game designers for *inventing new concepts*. The following section describes two methods that were important for this work.

2.4 Game and Design Methodologies

As we have discussed, there is consensus that playful behaviour in captive animals is a positive welfare indicator, and that therefore the introduction of enrichment that stimulates playful behaviour might be beneficial.

There is increasing recognition that games and interactive devices can play an essential role in stimulating species-specific behaviours. Moreover, we have described how several ACI researchers have suggested methods for working with non-human animals that are grounded in playful interactions. Since we needed to generate new ideas for playful interactive enrichment suitable for elephants, it seemed appropriate to investigate the techniques used by game designers to support ideation and rapid development.

2.4.1 Game design

Traditionally, games are thought of as structured social activities with a competitive element, played either in teams or between two players. There are forms of games in every major culture, from Mah Jongg in China and Backgammon in Arabia to Canasta in South America and Carrom in India. The field of game design offers many insights into why people become engaged with interactive playful systems. Our challenge is to apply these to another species.

Game design for humans usually centres on a dynamic that is a simulation of an ancient instinctive behavior. Humans are omnivores with a background in hunting and gathering, avoiding large predators, fighting for territorial rights and ultimately bartering for goods. Consequently we are drawn to games where we have to use the skills that were required to excel at these activities – survival mechanisms such as chasing and evading, utilizing quick reflexes, rapid decision-making, physical prowess, target practice, teamwork, social skills, asset management, trading and collecting etc. Some of these skills have become stylized in the context of board games and computer games, others are less diluted and more overt in the world of sport. The rewards are virtual survival on the playing field and real kudos in the form of peer approval.

Braithewaite and Schreiber (2009) describe game design as an art form, which is in essence about creating opportunities for players to make decisions that affect the outcome of the game. Salen (Tekinbas) and Zimmerman (2004) coined the term “meaningful play” to describe what happens when the actions of players have clear outcomes in the context of a game. Thus, the challenge for an ACI designer is to design a system that motivates non-human animal players to use it and engage with its core dynamic (Schell’s ‘game experience’). In order to play, the animals need to be able to make choices and have both the physical ability and the skill to control part of the game system, which would involve understanding some rules (mechanics).

There are many facets to game design, and designers approach the challenge in different ways. One popular ideation activity is the game jam, which is a creative production event designed to offer space and time for participants to work in teams and rapidly prototype game designs, sharing a common theme and constraints. Game jams originated in 2002 (Chen, 2017), and were designed to encourage innovation, experimentation and collaboration within the industry and its community. *Ludum Dare* (ldjam.com) was the first virtual event, attracting both professionals and students. Typically, in most such events, the source code for finished games is required to be shared, thereby facilitating a supportive, open-source tradition. *Global Game Jam* (globalgamejam.org), founded in 2008, is now the largest game jam in the world, its 2020 website claiming: '*…we had 934 locations in 118 countries create 9,601 games in one weekend!'*

What makes a game jam different from the usual brainstorming session that happens when a designer is given a brief? Kultima (2015) defines game jams as: '*accelerated, constrained and opportunistic game creation events with public exposure*', explaining how the 'take-aways' may differ from one participant to another, depending on their interests.

It is important that the event is *limited by time* (e.g. 48 hours), as this puts pressure on designers to come up with a viable solution quickly, so that it can be taken to the next stage – prototyping. The deadline facilitates collaboration and cooperation; everyone in the team has ideas, but compromises must be made in order to achieve success. In fact, it is a common experience of jammers that they can achieve tremendous creative output in a concentrated period of time, because they are working with no distractions in a supportive atmosphere with other focused people (Falk 0leson, 2017).

Another important facet of the game jam is the *theme*, which is only released at the start of the jam, to create a level playing field for participants and ensure that people do not try to lever their pre-conceived ideas – again, this supports meaningful collaboration. Since we were committed to working with animal experts as part of our enrichment development process, a game jam seemed to hold potential as a suitable vehicle to engage a range of stakeholders with a specific design brief that invited a multiplicity of creative interpretations.

Game jams have been compared with hackathon events and rapid prototyping methods (Kultima, 2015), partly because there is a strong sense of achievement at the end of a jam, with participants having a tangible product, albeit in a prototype state. In this respect, a game jam can be the start of a research process in which new conceptual knowledge is developed through the evolution of artefacts, as in Research through Design (RtD).

2.4.2 Research Through Design

Research through Design (RtD) is a framework that was developed to foster design innovation. It emphasizes the creation of knowledge through *reflective design practice* and the *making* of a series of physical objects, whereby the choices made by designers are inherent in the objects that are designed, presupposing that a series of such objects will be developed in order to reveal the evolution of the concept through its manifestations. RtD offers a useful method for exploring the *nuances* of design choices, some of which may not contribute to a final product, but nevertheless contribute to our knowledge of a complex topic.

This knowledge is embodied in the artifacts themselves (Gaver, 2012; Zimmerman et al., 2007), with theory providing context and relevance in the form of annotations on the documented designs. With regard to the type of knowledge expressed through a designed object, Gaver (2012) explains that each artifact is the culmination of a series of decisions made by the designer and that the artifact is therefore an exemplification of those choices. Moreover, the RtD method involves the *documentation* of designs, specifically for *future* objects and scenarios, encouraging designers to contemplate the possible impact of their work. Thus, the creation of real designed objects and the documentation of their creation are the main outputs of this type of design research.

Lowgren (2016) claims that *making* is required to effectively explore unknown interaction models - those for which there currently exist no idioms. Making is distinct from designing (an object) because it places emphasis on practical considerations, such as fabrication methods, functionality and, importantly, community involvement. In his definition of making, Lowgren includes '*construction, programming and other craft-like activities'*, and suggests that traditional prototyping favours black box making because it is focused on the outcome. However, concomitantly with the advent of ubiquitous computing and the increasing availability of physical prototyping components, un-boxing (revealing the mechanisms that provide functionality, rather than concealing them to present only the interface) is becoming increasingly relevant in the design and DIY (Do It Yourself) communities, because the making of the object (how-to) holds interest for people.

There has been a proliferation of websites (such as instructables.com, makezine.com) that offer guidance on how to DIY. Locoro et al. (2017) explain how ABC (whereby real, physical objects – atoms – are embedded with technology – bits – hence **A**toms **B**its **C**onvergence) describes the phenomenon of the currently expanding technical making community, and claims that the key features of ABC are: (i) knowledge artifacts, which can be represented in various media; (ii) community, including makerfaires and hack spaces; (iii) marketplaces, such as DIY 3D model emporia, as well as the proliferation of online outlets for cheap components; (iv) interaction, in all its forms, and (v) repositories, such as GitHub (github.com) and other opensource sharing platforms.

There seems to be agreement amongst RtD practitioners that, as the creation of prototypes transforms abstract concepts into concrete artefacts, this simultaneously allows the designer to share their ideas, facilitating first and second order knowledge generation (Bardzell et al., 2016) – in other words, allowing others to understand and question design choices that have been made through their own experience with the work; the designer gains first order knowledge through the process of designing and the user gains second order knowledge by interacting with this physical design. Mousette (2012) and Buxton (2007) both highlight the advantages of making what they call a physical “sketch” – an approximated physical demo – compared with creating a physical “prototype”, which can be thought of as a more fully realised concept, since it needs to be sufficiently developed so as to be testable as a possible solution. Mousette offers a simplified explanation of a *sketch* as a tangible version of a wireframe (deployed in early design iteration and user testing to offer users a chance to try an interactive demo via an interface). Buxton ascribes the following features to a sketch: evocative, provocative, tentative, non-committal, exploratory and questioning. *Prototypes*, on the other hand (according to Buxton), are more refined, they answer questions and describe solutions; they are specific and necessarily didactic, since they present a possible response to a brief that the user of the prototype must learn how to engage with – if well-designed, the device leverages affordances to teach its user what to do.

Redstrom (2017) describes this kind of design research (RtD) as having two distinct directions – on the one hand, it can be presented as a series of ‘*unfolding experiments*’ and on the other as a set of ‘design definitions’ that have clear implications (p.117). These two aspects are strongly connected, as the design experimentation often inspires the insights that inform the evolving theory (derived from the design definitions). The act of designing is a process that requires theoretical considerations, related to the decisions made by the designer, in themselves based on analyses of previous design iterations. This is a progressive maturation of ideas made real through craft. For Lim et al. (2008), these versions of the design are ‘*filters that transverse a design space*’, thereby making the possibilities and limitations of the design obvious and measurable. Raptis et al. (2017) refer to the strings of concepts developed by designers as ‘*provocations*’ and suggest three evaluation criteria that might be applied to all such designs – aesthetic, functional and conceptual. Gaver (2012) similarly proposes different types of knowledge that an artifact might be said to express – aesthetic, functional, social, philosophical – with the understanding that these can be described although not directly measured.

Indeed, the *measurability* of a design is a somewhat contentious issue, for what metrics can we use? One of the challenges that some researchers have identified with RtD (Zimmerman et al. 2010; Bardzell et al. 2016) is the apparent current lack of evaluation criteria, yet the idea that RtD outputs can be verified in some way is seen as attractive, in order to validate it as a method in line with other methods applied by the scientific and HCI communities.

Part of the issue is the *particularity* of RtD outputs, which are often unique, highly specific and context dependent. Bardzell et al. (2016) find this to be problematic, asking whether such designs can ever be legitimized, because their distinct nature means they cannot be used to support a generalized theory. The designs may raise more questions than they answer and, moreover, may not fit easily into a more general body of work, thus making it difficult to draw broader conclusions that contribute to a wider theoretical framework (Gaver, 2012). Gaver, on the other hand, emphasizes the individual and conceptually rich outputs that are generated as a strength of the RtD approach. Indeed, he explicitly contrasts RtD outputs with the kinds of theories generated using a '*design patterns*' (Alexander, 1977) approach that draws general principles from large bodies of work, pointing out that RtD outputs can be the inspiration for wider research projects. He also makes the point that since RtD is a useful method for exploring new problems and offering solutions that are manifestations of ideas, the results are highly likely to be unique and specific to their situation.

One way of measuring the success of a design is by determining how well it meets the original brief. RtD projects tend to have broad, ideological aims (i.e. a *philosophical* aspect) that invite an infinite number of interpretations – e.g. '*engage public with electricity use and environment*' (Gaver et al., 2015); '*find out how kids would like to communicate remotely*' (Giller et al., 1999). There is therefore a lot of opportunity to brainstorm and play with ideas. Even if designers generate numerous *concepts*, they will never be able to exhaust the realm of possibilities, because there is no limit to what can be created. When the original brief is so broad in scope, it becomes problematic to judge a particular design because any number of other designs might also have been equally fit for purpose. Yet it is possible to demonstrate the value of a design as a generator of knowledge; it is possible to assess whether a design has helped the developers come closer to reaching their stated goals, but equally, a novel design can stimulate new perspectives and trigger changes in direction. It is therefore important to *articulate* the strengths of designs and *explain* the rationale for their development.

Bardzell et al. (2016) propose three key aspects to be considered when documenting RtD: (i) the medium, which is typically a collection of media, aggregated to form a cohesive expression of a relevant aspect of the design; (ii) performativity, which means that the documentation itself is a call to action - a process resulting in a series of sketched proposals, rather than finished representations;

(iii) the documentation, which should at the same time work as a set of resources that enable conceptual knowledge to be shared.

It seems clear that a range of media will express the nature of design work more effectively than text alone. Jonas' comment: '*Good design should be able to explain its own emergence*' (2006, p.2) begs the question – how? In this regard, Gaver (2012) stresses the utility and importance of keeping an annotated workbook that shows transitions over time. He suggests that multiple perspectives are revealed through the (visual) presentation of many design examples. Zimmerman et al. (2010) also support this method of documentation, stating that designers should show how their perceptions of the problem or brief change over time, and specifically what triggers the change. Bowers (2012) also supports the notion that an annotated portfolio is a constructive and viable method for documenting new designs.

This idea is endorsed and explored by Nick Sousanis in the context of a comic book thesis ('Unflattening' 2017), in which the author demonstrates in a very effective manner '*the spatial interplay of sequential and simultaneous'* that results from presenting information in a one-page layout, and using graphics as well as text to capture the reader's attention and convey complex concepts. He contrasts this form with the linearity of traditional academic writing, claiming that the more holistic approach of the comic offers cognitive benefits for the reader. Dykes et al. (2016) develop this point of view, arguing for comics as a viable alternative to design notebooks because they have their own idioms allowing the writer to situate text in different ways – e.g. speech bubbles, captions, labels – and that this aids comprehension.

Although his work is strongly graphical, Sousanis describes it using the terms '*seeing'* and '*visual'* to '*encompass other ways of making meaning and experiencing the world*', making reference to dogs' perceptions as an example of how another species can use different senses and gain knowledge about a parallel universe – one that we inhabit but do not perceive or understand very well. Therefore, if researchers and designers plan to make their ideas accessible, they should explore ways of communicating them using different media and modes.

The kinds of designs envisaged within RtD are not only tangible objects that we can perceive; they are also interactive. Interaction designers appreciate that their work cannot stand alone but must be actively experienced by users in order to be validated. While the same could be said of any artistic endeavour (e.g. reading literature, listening to music), the interplay between the user and the object is critical in interaction design, a field which examines the nuances of that exchange. This means that the *functionality* of an object is critical, because inherent in the functionality is the *control* that a user has over this aspect, even if this is as basic as switching it on and off. The *interface* of a system is the perceptible ‘surface’ that enables the user to *interact* with the underlying *system* that encapsulates the functionality. In addition to functionality, Gaver believes that the *aesthetic* aspect is crucial, since the form and representation of a design support its ability to function as an interactive device. In his description of design provocations, Raptis (2017) describes how aesthetics can be deliberately non-pleasing or unexpected in order to spark interest; for him, the whole point of design provocation is to foster high levels of engagement, addressing the overarching goal of the design exercise, which is to somehow challenge widespread opinion.

Zimmerman et al. (2010) provide a critique of RtD as a method for generating knowledge via design research, highlighting the following advantages: (i) it is useful for making inquiries into complex situations; (ii) researchers focus on future (non-existing) designs, leading to (iii) consideration of the associated ethics and potential outcomes. According to Zimmerman et al., what distinguishes RtD from qualitative or quantitative fieldwork is that it: ‘*focuses on uncovering important relationships between phenomena in the near and speculative future, and not in the present.’*

The case for using an RtD approach to support our investigation of suitable interactive devices for animals is compelling – the context is complex, the concepts are all new and never previously attempted, the ethical dimensions hold interest for a variety of stakeholders. Moreover, the emphasis on physically *making* versions of the design – exploring both functionality and aesthetics – suited the ideation, technology embedding and crafting processes we planned to undertake. In the next section, we present some thoughts on aesthetics, suggesting how this aspect of design might be relevant for our work.

2.5 Aesthetics

Consumer-driven design for humans places great emphasis on *aesthetics*, which in popular parlance has come to mean the sensory qualities of an object or image that give it broad appeal. The aesthetic principles that Western humans have traditionally valued tend to be strongly associated with our visual perception, exemplified by modern dictionary definitions – (i) Merriem-Webster (merriem-webster.com) define the adjective 'aesthetic' to be 'relating to beautiful, artistic, attractive (*pleasing in appearance*)'; (ii) Cambridge English Dictionary (dictionary.cambridge.com) describe it as: 'relating to enjoyment or study of beauty, showing beauty'. Yet the aesthetic qualities of an experience vary considerably from species to species, depending on which sensory, cognitive and physical characteristics mediate the animal's perception and interaction with its environment (French et al., 2020). In consequence, an exploration of alternative sensory and related affective values is required in order to understand which range of qualities have appeal for non-human animals.

Environmental enrichment aims to enhance the psychological and physiological welfare of captive animals by promoting species-specific behaviours. Differences between species are expressed in their normal behaviour, such as how they interact with the world and with their conspecifics, what their daily activities are and how they perform their usual routines. It is evident that aesthetic sensibilities vary when we compare the activities of different animals. For example, Plotnik (2010) reports that, as a part of their self-maintenance and social bonding routines, chimps spend time grooming each other while elephants have mud-baths and spray dust on their bodies. In both cases, these activities enhance the health of the animals' skins while also providing significant tactile stimulation, except that the chimps are removing dirt while the elephants are applying it. These differences in daily practices and aesthetic experiences influence the way in which different species respond to external stimuli, sometimes leading us to misinterpret their capabilities. For instance, the mirror recognition test, typically used to verify whether an animal is capable of self-awareness, involves painting a mark on an animal's face and checking to see if the animal touches the mark when they look at themselves in the mirror, implying that they recognize their own reflection. Plotnik's theory is that, given their grooming habits, chimps might be expected to notice a strange mark on their bodies; on the other hand, given their bathing habits, it is hardly surprising if elephants pay little attention to such a mark and, if they do not, it does not necessarily mean that elephants are any less self-aware than chimps.

2.5.1 Aesthetics as a cultural experience

Aesthetics as a philosophy deals with what is pleasing to the senses, emotions and intellect. It is not simply about what we perceive, but more importantly about how that perception affects us at a visceral and cognitive level. Even within humans, let alone between humans and other species, there is debate as to whether it is possible to talk about 'universal aesthetics' (which would be shared by everyone), because many modern philosophers believe it is inevitable that judgements about aesthetic quality are embedded in cultural contexts and prior experience (Bourdieu, 1984).

For example, in Western culture, aesthetics has been strongly influenced by the work of Greek and then Medieval scholars who emphasized ideals and perfection in design. These ideas tended to be abstract, leading to a regimented approach to artistic representation that focused on things like proportion of form (as in classical Greek sculpture) while often ignoring self-expression (Scruton & Munro, britannica.com). While a connection with nature was deemed essential for artistic expression, this was in the form of *mimesis* – whereby a designed artifact was expected to imitate a natural form in a formal and figurative manner. In the 19th century, Hegel broke away from this tradition, claiming that beauty is a manifestation of freedom, impossible to present in a regular symmetrical form, owing its nature not only to harmonious relationships between components but also to its inherent 'spirit' (Stanford Philosophy).

By contrast, the Japanese approach to aesthetics encompasses a more holistic appreciation of the designed object (Koren, 1994). In a philosophical sense, the object represents its place in society, always embodied in context. A well-known example of this design aesthetic is the concept of *Wabi-sabi*, denoting artefacts organic in form, inspired by or derived from nature, unique (one of a kind), personal, crude or rough, and encouraging the expansion of sensory engagement – very unlike the Western idea of mimesis. Emphasizing the role of intuition and unconventional ways of thinking in design aesthetics, Koren (1994) points out how Wabi-sabi '*exemplifies many of Zen's core spiritual-philosophical tenets*.' He states that Wabi (roughly translated as 'subdued, living in nature') references a way of life, a subjective perspective, a philosophical construct and the spatial arrangement of objects; while Sabi (historically meaning 'rust or impermanence') references aesthetic ideals, materiality, an objective perspective and, crucially, the passage of time. This is why weathered or disintegrating objects may poignantly express Wabi-sabi, reminding us that all things pass. This sense of mortality and melancholy is also illustrated by the term '*mono-no-aware'* which refers to and celebrates the transience of things; this is an awareness to which the annual cherry blossom *Hanami* festival is closely related.

The examples above show how two human cultures have developed distinct aesthetic sensibilities, which would support the argument that a 'universal aesthetics' may not exist. It may equally be true that there exists no 'one-size-fits-all' approach when designing artefacts for non-human animals. As humans know from experience, the spice of life is to be found in variety – and this may hold true for other animals (Taylor & Mills, 2007). Although the philosophical features of Wabi-sabi (such as celebrating impermanence) might be irrelevant for an animal, the emphasis on natural forms and evidence of history might hold some interest for a species for whom classical form (and its representational function) has no value but whose sensory apparatus can appreciate other things, such as the tactile qualities of an object and the immediacy of chemical signals.

2.5.2 Aesthetics as a multidimensional experience

The word *aesthetic* derives from Greek, meaning 'sensitive … pertaining to sense perception or sensation' (Etymology Online etymonline.com), which suggests a wide experience of pleasure conveyed through the senses. In contrast to the visual aspects which are still retained in popular definitions of aesthetics, in Ancient Greece, aesthetic values were applied to all the arts, including music, poetry, architecture and drama. These were important media that served to both entertain and educate, whereby an aesthetic experience became the vehicle for intellectual growth and moral development (Scruton & Munro, britannica.com).

In contemporary design, a range of physiological dimensions come into play, reflected in the great variety of shapes, textures, sounds and smells featured in many everyday objects. For example, the smooth surfaces and rounded edges of mobile phones are designed for enjoyable hand-feel as much as visual appreciation. However, until the 20th Century, the discourse on aesthetics in product design was mostly limited to visual aspects, possibly because vision is such a prominent sense for humans. Indeed, Diaconu (2006) suggests that olfactory aesthetics has been neglected because of its ephemeral nature and our lack of sensitivity to smells, and the resulting poverty of linguistic expression with regards to olfaction. More recently, Huss et al. (2018) have explored olfactory aesthetics in relation to humans' relationship with flowers, describing this as an embodied aesthetics whereby we experience pleasure through interactive stimulation.

A parallel perspective is found in the recent conceptual framework of *Somaesthetics*, developed by Richard Shusterman (2013). This emphasises that beauty is not only related to the visual experience, but also to the appreciation of other embodied sensory experiences, including feelings derived from physical actions. Others have built on this, suggesting variations that focus on human experiences of sound, touch and the resulting perception of design itself (Maus, 2010; Schiphorst, 2009; Hook et al., 2015).

Rooted in Dewey's exploration of aesthetics as an emergent phenomenon (McClelland, 2006), Flanagan proposes an aesthetics involving the temporal interplay of dimensions of experience other than the usual five senses (2015). She attempts to define a 'ludic language' emerging from gameplay and game design, arguing that the prevalence of play culture has permeated other media to the extent that it has created new linguistic frames of reference. A game designer's craft is to sculpt player experience – itself a multisensory and intellectually engaging activity – so that it is as pleasurable as possible. Flanagan shows that it is possible to make judgements about the intrinsic values of particular game design components, based on how they affect human emotions and intellect, just as it has been possible to apply a value system to visual aesthetics. Flanagan describes well-known game elements such as control systems, inventories and HUDs (Heads-Up-Displays) as memes, entering the language as experiential components. These elements are not directly related to individual senses, but encompass the overall *performative* experience of play, which involves both subjective duration and enactment of gameplay sequences. The temporal aspects of gameplay and the performance itself are therefore identified as having their own distinct aesthetic values (Flanagan, 2015).

This widening of perspective on what constitutes aesthetics can help inform design work for non-human animals, for whom 'doing' is an essential part of their aesthetic experience – since their sensory input relies heavily on active engagement (sniffing, keeping watch, touching and moving objects, eating and so forth). Although some experiences are passive, such as lying in the sun and feeling the heat, life for most adult wild animals is a matter of constant vigilance and activity in order to survive and reproduce (Young, 2003). All species have therefore evolved to have heightened sensory, physical and cognitive abilities that promote their survival; this suggests that it might be interesting for ACI designers to investigate these species-specific perceptive abilities in order to enhance the aesthetic dimension of their designs for animals.

2.6 Summary

This chapter has briefly covered the history of Animal Welfare, from early days of domesticating livestock and dogs (16,000 years ago) to the first texts that advocated non-violence to animals (3000 years ago); from the first philosophical vegetarians (2500 years ago) to the suggestion by Bentham that animals were sentient (1800s); from anti-vivisectionists to animal rights (1900s); from criticism of intensive farming (1960s) to the Five Freedoms (1970s). We have reached an era where the 3Rs and the concept of ‘a life worth living’ have led to the accepted use of environmental enrichment for animals kept in captivity.

We then discussed some principles of environmental enrichment, including the provision of control and choice, the welfare potential of play and how technology is enabling new kinds of interactions between animals and novel enrichment systems. This is the realm in which ACI practitioners practice their research, and we presented an overview of recent work that shows a variety of methods for designing and developing systems for animals. All of these emphasise prior understanding of the non-human animal user.

The next section addressed game and design methodologies, where there is also a need to appreciate players and users in order to create the best possible designs. We focused on how Game Jams support concept development and how Research through Design offers a structured method for exploring prototypes and documenting insights. Finally, we gave an overview of aesthetics, showing how perspectives are culturally specific and how there is contemporary interest in performative aspects of this dimension of design.

Methodology

This chapter of the dissertation explains how the research questions delineated in Chapter 1 have been approached, building on previous work in ACI and taking inspiration from novel methods for developing new ideas in HCI and games. We discuss how different methodologies have shaped the methodological approach for this work, how they have been applied to address the main research questions and, critically, what other important factors may need to be considered when working with elephants and other animals.

An Overview of Methodologies is shown in Figure 2. The diagram uses icons to show where wild and/or captive elephants have been involved in the methodological process, and where we have collaborated with human experts.

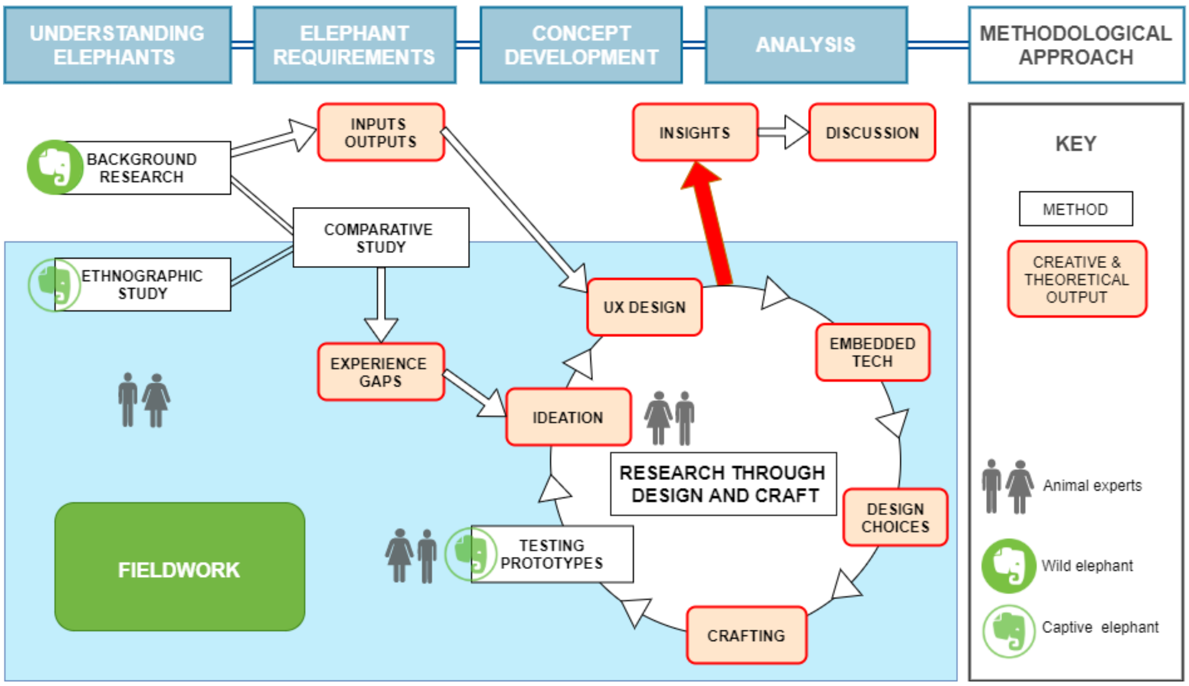


Figure 2: Overview of Methodologies

The methodological approach comprises of 4 steps (blue boxes at the top) and each of these are described in the subsequent text, indicating how the other elements of the diagram are incorporated. The rest of this chapter is divided into four sections representing the four steps of the diagram: (i) Understanding Elephants; (ii) Elephant Requirements; (iii) Concept Development; (iv) Insights and Analysis.

3.1 Understanding Elephants

To address the challenges that derive from interspecies differences (see *Chapter 2*), ACI methodologies start with a detailed examination of the end-user, which includes researching the physical and behavioural characteristics of the target species. We have also adopted this approach as part of the preliminary stage of the project: *Understanding Elephants.*

In order to work with animals in any capacity, permission and advice needs to be sought from professionals involved with animal welfare and husbandry. Gaining ethics approval is a prerequisite for undertaking research with animals housed in an institution and obtaining feedback from animal experts is critical for designers who have a background in Computer Science. It was therefore important to build alliances with animal experts and zoo personnel, who could validate design decisions and facilitate access to elephants, as well as offering important insights and suggestions. These collaborative opportunities are explained in *3.1.1 Expert advice* below.

To understand the potential benefit of playful technologies for captive elephants and to begin to design a playful interactive system for an elephant, we needed to gain an appreciation of their cognitive abilities, as well as an understanding of how elephants typically interact with the world and their conspecifics. Various complementary approaches were adopted in order to tackle the problem from different angles.

In the first instance, to understand more about the potential users (elephants), a comprehensive literature review of elephant behaviour was undertaken, as described in *Chapter 4: All About Elephants – Elephant Lifestyle*. In order to gain an appreciation of real elephants in their habitual context, an ethnographic study was undertaken at Colchester Zoo (Essex, England) – *Chapter 4: All About Elephants: Elephants in Captivity* – with additional observational work documented at Howletts Wild Animal Park (Kent, England), Dublin Zoo (Dublin, Ireland), Blair Drummond Safari Park (Stirling, Scotland), Twycross Zoo (Leicestershire, England), Noah's Ark Zoo Farm (Bristol, England) and Skanda Vale Ashram (Carmarthenshire, Wales).

- https://www.colchester-zoo.com/
- https://www.aspinallfoundation.org/howletts/
- https://www.dublinzoo.ie/
- https://www.blairdrummond.com/
- https://twycrosszoo.org/
- https://www.noahsarkzoofarm.co.uk/
- https://www.skandavale.org/

3.1.1 Expert advice

Consistent with ACI practice (Robinson et al., 2014), we conducted interviews with a range of experts on elephants' and more generally animals' behaviour, in order to obtain feedback on ideas and discover appropriate directions for the work (see *Appendices A3: Meeting with Experts* and *A4: Colchester Questions for Keepers*). In the first instance, contact was made with the research and education officers at zoos and wildlife parks close to London. Colchester Zoo connected us with both BIAZA's Elephant Welfare Group (EWG, 2020) and the Colchester Head Elephant Keeper, allowing us to undertake observations as well as speak to keepers.

Lisa Yon (Vice Chair of EWG) firstly introduced us to other group members via a Skype consultation in 2013, during which we discussed the project and gained feedback on ideas. Lisa Yon also forwarded the project details to Ros Clubb from EWG and Phyllis Lee from Amboseli Trust for Elephants (Amboseli, 2020) for detailed feedback via email.

An early idea for our project with elephants had been to create toys and games that could be enjoyed together by captive elephants and their human carers. We imagined a scenario where human and elephant could understand each other through the shared notion of a game such that each understood the rules of engagement, where the lingua franca would be the pragmatics of play – in other words, how each player uses play concepts to create meaning about what is happening during the game, thereby enabling the game to exist as a cooperative activity. We know this happens amongst humans, transcending cultural and language barriers, and can also be observed across species, as we have discussed. However, as our project progressed, the ambition of designing a shared toy or game that would enable communication between elephants and humans gradually evolved into the idea of creating a playful system just for elephants. It became clear from the EWG discussion that animal welfare experts actively discourage close relationships between elephants and people, since this distorts the elephants' natural behaviour patterns - wild elephants do not cultivate friendships with humans, after all.

Food was observed to be the strongest motivator for interaction. Beam-breakers were recommended as hidden sensors for detecting interactions and pipes large enough to fit an elephant's trunk were proposed as potential interface elements, since elephants like to explore places with their trunks.

After the conversation with the EWG, it became possible to undertake an ethnographic study of the elephants at Colchester Zoo (2014) – see *Elephants in Captivity* below. Unfortunately, there were few opportunities to talk to keepers because of differing time constraints and keepers' duties. The primary researcher had a short meeting with the Head Elephant Keeper, during which an attempt was made to discuss possible enrichment ideas (Transcript in *Appendix A3: Colchester Questions for Keepers*). It seemed clear that the elephant team was skeptical about being involved in an ACI project and were unwilling to entertain the idea of trialing interactive prototypes as required to fulfil our purposes. Furthermore, there was some concern regarding time commitments and the difficulty of manufacturing anything that might withstand the attentions of an elephant. In retrospect, it became obvious that the proposal submitted to the zoo was much too vague for those stakeholders to assess.

Consequently, and in order to expand knowledge in the area of environmental enrichment, the primary researcher participated in a Shape of Enrichment (SHAPE, 2020) workshop focused on designing and implementing enrichment at a wildlife sanctuary (Lakeview Monkey Sanctuary). An overview of the workshop is provided in *Appendix A5: SHAPE S.E.E.C.* This experience provided us with one of our fundamental guidelines: ensuring that *enrichment goals* are clearly stated and understood by the design team, including gatekeepers such as zookeepers and managers. Additionally, working in a small team with zookeepers underlined the importance of keeping all stakeholders involved and of allowing the animal carers to retain ownership of the final product.

Thereafter, in subsequent meetings with elephant keepers, the primary researcher was more confident about expressing ideas and explaining how technology had the potential to enhance animals' interactions with their environment, thereby gaining opportunities to conduct fieldwork involving prototype systems.

Discussions with Mark Kingston-Jones (Workshop Coordinator and Instructor with SHAPE) led to contacts with other elephant keepers at Skanda Vale Ashram, a multi-faith monastic community in Wales, and Blair Drummond Safari Park in Scotland, while Lisa Yon introduced us to Hannah Buchanan-Smith, an expert in animal behavior at Stirling University. Speaking to Hannah Buchanan-Smith highlighted the importance of offering control to the animals in order to reduce stress, while talking to Mark Kingston-Jones highlighted the value of playful behaviour as an indicator of good welfare.

The feedback from welfare experts and elephant keepers was invaluable throughout the project and is summarized in the relevant sections of this dissertation.

3.1.2 Literature review: Elephant lifestyle

Consistent with established practice within ACI research and design (Resner 2001), an extensive literature review of elephant lifestyle, cognition and communication was undertaken, in order to appreciate the sensory and cognitive apparatus of elephants, and how they behave in the wild. (See *Chapter 4: Understanding Elephants.*) For example, this showed that elephants use acoustic, chemical and tactile senses for interacting with the world, relying less on vision, suggesting that designs should be informed by these interaction modalities. With regard to lifestyle, being social (living in a herd) means that elephants' communication is complex and wide-ranging. For example, wild elephants have developed the ability to distinguish between herd members and identify different calls, suggesting that, as the majority of captive elephants miss the opportunity to live in a large herd, cognitive and sensory stimulation that focuses on acoustic enrichment might be appropriate to explore.

3.1.3 Ethnographic study: Elephants in captivity

Aware of the need to work with real elephants in order to develop concepts and prototype ideas, we undertook fieldwork observing captive elephants, in order to understand how their lifestyle differs from their wild counterparts, and to thereby identify gaps in experience that might be filled with novel enrichment ideas. This work provided us with rich insights into the varying experiences of captive elephants and importantly, facilitated networking opportunities with keepers.

During observation studies of Colchester Zoo's elephants over three months, we noted what activities the animals were doing during hour-long periods and built a table showing an overview of behaviours, including which parts of the body were involved (see *Appendix A6: Ethnographic Data*). We made a note of which naturally occurring wild elephant behaviours seemed to be missing from the repertoires of the captive animals that were visited and also what kinds of exercise they were undertaking.

It was very useful to make sketches of the animals, as this activity sharpens one's perception and draws attention to salient features. Self and Pei (2014) claim that sketching during conceptual design "provides opportunities for previous frames of reference to re-emerge and be re-engaged in new ways." In other words, creating a visual representation of a phenomenon can help trigger unexpected connections within the brain network. This idea builds on work developed by SchÖn and Wiggins (1995), who sought to explain how we construct meaning as we register information through our visual sense. For the author, this enabled a better appreciation of elephant anatomy, such as the trunk, by close observation of its movement and utility.

The author also adopted a creative writing method for personal reflection, with the aim of facilitating an understanding of an elephant's perspective on the world and perhaps being able to empathise with a captive elephant. On the one hand, this was a brainstorming technique and a feat of imagination; on the other, it was a way of attempting to map elephant interests, anatomical features and sensory modalities to those of the human species. In this respect, the writing shares some features with the Design Fiction approach used by North (2018), who was trying to understand what it is like to be a horse and communicate using ear gestures.

Observations carried out within the study revealed some of the playful behaviours of the animals, showed their range of movements and interests during discrete time periods and clarified hierarchies within the herd. Interviews with the Head Elephant keeper were useful for explaining the animal husbandry routines in place and for shedding light on the different characteristics of the animals. This information was supplemented by later observations of a small herd of African elephants at Howletts Wild Animal Park, two African females at Blair Drummond Safari Park, two African males at Noah's Ark Elephant Eden, a small Asian herd at Twycross Zoo, an African herd at Dublin Zoo, our main user-tester, an Asian female at Skanda Vale Ashram and her conspecific, another Asian female re-homed from a circus.

Following the literature review, expert interviews and field observations mentioned above, we attempted a comparative study – comparing the lives and behaviours of wild and captive elephants in order to identify some gaps in experience of the captive animals, so as to define possible enrichment goals. This work is explained in the following section, *Elephant Requirements*.

3.2 Elephant Requirements

There are 2 distinct aspects to this part of the research, to which the following questions relate:

(i) How could an elephant INTERACT with a technology-enabled system? In other words, what are interface design requirements?

(ii) How can we imagine what might be inherently interesting and useful for a captive elephant? In other words, what might such a system offer an elephant in the way of an appropriate experience?

Knowing what modalities elephants use to interact with each other in the wild and in captivity informed the design of the enrichment experience. Detailed knowledge of elephant communication (preferred modes of interaction) and dexterity (physical abilities) was required, both in order to develop an interface that was usable and to ensure the system offered an experience that an elephant could appreciate.

All our work has been guided by the fundamental principle of environmental enrichment that every intervention must have a clear *enrichment goal.* Since environmental enrichment aims to encourage species-appropriate behaviours across a range of categories, we proposed that an interactive system should aim to give the captive elephants an experience that shared some of the features of an experience enjoyed by a wild elephant, or which encouraged the elephant to practice some of the skills that a wild elephant would naturally deploy. Zoos and wildlife parks currently offer their elephants a range of enrichment, therefore In order to motivate potential ideas for novel enrichment devices , we attempted to identify some of the gaps in the experience of captive elephants compared to their wild counterparts, with the aim of using technology to offer something new (French et al., 2015).

The behaviours observed in captivity were compared with behaviours recorded in communities of wild elephants (from the academic literature). This work is presented in *Appendix A6: Ethnographic Data*. Based on our findings, we identified the following experiences and associated behaviours as having potential for expression via enrichment (for some groups of elephants), in cases where a natural alternative was not attainable:

1. Acoustic experiences – e.g., antiphonal calling, opportunity to identify multiple family members, stimulation at appropriate frequencies. Such experiences are fundamental for establishing and maintaining social bonds.
2. Olfactory experiences – e.g., scents of multiple elephants in different physiological states, novel environmental features.
3. Cognitive challenges and the need to adapt – e.g., route-planning, foraging in unfamiliar terrain, dealing with conspecifics, exercising control over own behaviour, making meaningful choices about when and where to eat, drink, bathe, play etc.

4. Social experiences – e.g., being able to choose companions, fellowship within a herd, allomothering, play-fighting.
5. Physical exercise – e.g., opportunity and motivation to walk for long distances.

This information provided the basis for subsequent brainstorming and concept development, as we were aiming to design playful systems that would encourage the expression of evolved behaviour patterns (such as those recorded in the literature about wild elephants) in the zoo-housed animals. Moreover, we wanted to find out if technology could enable some of our enrichment ideas.

Supporting some of the areas where enrichment might be beneficial was outside the scope of our project. For example, if wild elephants all go on daily twenty km hikes with their extended families, UX designers have no opportunity to offer captive elephants a similar experience. None-the-less, it is possible to promote regular exercise and try to maintain small herds; however, such a captive lifestyle will not be as rich and rewarding in terms of cognitive, sensory, social and physical stimulation.

For the purposes of this research, we tried to identify small achievable goals within the scope of the project, rather than, for example, attempting to design completely new wildlife park environments. This has enabled us to focus on specific details of user interactions, thereby generating some reusable designs which could be framed in different contexts.

3.3 Concept Development

One of the most challenging issues for a game designer is to try and imagine what kind of experience another might enjoy. In the field of Game Design, Jesse Schell (2008) states: '*The most important skill for a game designer is listening (to the players)*.' Arguably, in the case of another species we needed to broaden the scope of Schell's call to 'listen' to include the use of other senses that might help us to make sense of an elephant's experience. When elephants deliberately communicate with each other, they do so using different modalities – visual communication involves exchanging gestures, aural communication may occur using infrasonic rumbles that are inaudible to humans, while olfactory communication includes leaving scents for others to pick up. Obviously, when exploring different design ideas, we could not ask elephants what they would like or what they thought of our prototypes, but keepers were able to read their body language and infer whether an experience was interesting or stressful.

Regarding the design of games for humans, Schell has developed a series of 'Lenses', each of which offer a particular perspective on the design process, and through which designers are invited to analyse their game designs. His Lens of Essential Experience asks the following questions: [1] What experience do I want the player to have? [2] What is essential to that experience? [3] How can my game capture that essence? In our context, this translates into:

- What experience do I want an elephant to have?
- What is essential to that elephant experience?
- How could a playful interactive system for elephants capture that essence?

User Experience (UX) Design requires a thorough understanding of the design context. In this case, there were two contexts to consider. Firstly, as previously stated, we investigated the lifestyle of wild elephants in order to understand the experience of captive elephants. Secondly, we needed to appreciate the environment in which captive elephants found themselves, which included the physical aspects of their enclosures and the organizational aspects of the institutions, as well as the many potential stake-holders – elephants, neighbouring animals, keepers, zoo management personnel, members of the public, animal behaviourists. These facets of the environment were context specific.

Concept development started with taking our enrichment goals as a reference and brainstorming novel ways to achieve them using technology to support suitable designs. We created labeled sketches to visualize the concepts and facilitate sharing. As ideas reached a usable stage, they were discussed with other human participants (elephant keepers, animal behavior experts) using a Participatory Design approach (French et al., 2015). Muller (2003) describes this as the third space in HCI - where developer and user can work together on fulfilling expectations. Indeed, Alexander and Beus-Dukic (2009) remark: *'(Requirements) are more often created by collaborative work than casually found.'*

3.3.1 ZooJam

As mentioned in *Chapter 2: Background Research*, we thought a game jam might be a suitable vehicle for developing new ideas to promote animal welfare, by encouraging the expression of natural behaviours through artificial means. A variation on a game jam – the ZooJam – was developed for multi-disciplinary brainstorming and ideation. Its aim was to extend the reach of UX Design beyond human experience in order to become inclusive of other species and their interactions with technology (French et al., 2019). The ZooJam format illustrated how games for non-human animals could target species-specific environmental enrichment goals – using the jam themes to guide jammers' creative outputs.

In 2018, a ZooJam was used as the vehicle for collecting ideas relating to elephants, in response to a brief offered by the author with Lisa Yon from the Elephant Welfare Group (French et al, 2018). Outputs from the ZooJam validated some of our earlier ideations as well as giving us fresh inspiration.

The outputs of these ideation sessions were assessed for feasibility and some were taken to a prototyping stage. By providing a range of options during the prototyping stage, it was possible to give elephants choices and thereby gain valuable user feedback. As designers, we initiated the process by second-guessing what an elephant might enjoy, but *interface designs* using *embedded technology* afforded us the opportunity to explore our concepts further and design systems that allowed elephant users to show us what they preferred. In some ways, this was a method similar to the rapid prototyping method applied by Robinson et al. (2014), except that in our case, the designs evolved over a longer period of time – years rather than days.

The work then evolved into a *Research through Design and Craft* project, whereby the process of *physically crafting a designed object* contributed to the design-in-progress. In addition, designs were manufactured to a sufficient degree of robustness to be tested with their intended users – elephants – which fed invaluable feedback into an iterative process.

3.3.2 Research through Design and Craft

As discussed in Chapter 2, Research through Design (RtD: described in detail in *Background Research - Research through Design*) emphasizes the creation of knowledge through reflective design practice and the making of a series of physical objects, where that knowledge is embodied in the artifacts themselves (Gaver, 2012; Zimmerman et al, 2007), with theory providing context and relevance in the form of annotations on the documented designs.

Each object we created was a multi-faceted experiment in making and it became a challenge to know how to present the work in a succinct way that would showcase the technical and design elements as well as evaluate the interactions these enabled based on user feedback. We therefore decided initially to use a RtD approach (French et al., 2017), with the result that the dissertation presents this part of the fieldwork as a series of *annotated workbooks*, with diagrams and photographs showing the evolution of designs and the rationales for the design choices made (discussed in the next section *3.4 Insights and Analysis*).

However, RtD workbook annotation places emphasis on the reasons for making design decisions *before* a prototype is generated, rather than attempting to evaluate the prototype after it has been tested. There is a cause and effect chain whereby the reasons are linked to the analysis of previous designs. Although Gaver (2012) is dismissive of what he calls '*a tendency towards scientism'* from the HCI community, whereby research problems are framed in such a way that they offer 'scientific proof' of theoretical knowledge – e.g. identify goals, turn into questions, find ways to assess – we found a goal-oriented approach to be useful for directing our creativity. We adapted the traditional RtD approach to encompass Research through Design *and Craft*, because the physical *making and testing* of our designs was so fundamental to the acquisition of knowledge.

Our concepts matured over time as they were filtered through stages of design, crafting, implementation and elephant response gathering. Importantly, the interface design and the system design were interrelated problems, with the evaluation of one feeding back into the design and development of the other, so that they progressed iteratively. This work in turn contributed to our understanding of an elephant as a prospective user of interactive technology, an aspect of elephant behaviour that has not been explored before. Referring back to our research questions, it soon became clear that, in order to answer the question '***Will captive elephants engage with playful technologies designed to enrich their daily experience?'***, much of the RtD&C work would revolve around finding answers to our second research question '***What playful technologies would elephants engage with, and how could these systems be designed to enable elephants to interact with them?'***

During the project, it became increasingly obvious how challenging it was to imagine the world from an elephant's perspective - what kinds of interactive toys would an elephant really enjoy? The belief that playful behaviour is its own reward and that a playful technology must have intrinsic value precluded the possibility of using food as a motivator - but what else would be valuable for an elephant?

For example, in the wild, an elephant would usually have a lot of space to explore in order to allow her to select the most comfortable or interesting location. In captivity, this might not be feasible, but it would potentially be possible to provide animals with some control over existing aspects of the enclosure, such as levels of light, heat or humidity, thus enabling them to change the environment according to their preferences. At present, these features are controlled by keepers, but some of the power to transform the environment could be transferred to the animals, by creating a bespoke interface to a computer-mediated system. We envisaged the provision of simple controls (such as switches for showers) for the elephants, which would enable them to realise that an interface can be used to create changes in their environment, which in turn would lead them to explore the potential of more complex interactive toys.

In parallel to the design and development of simple binary switch mechanisms, we investigated different kinds of acoustic outputs. In regard to auditory enrichment, the EWG experts' advice was that playing the sounds of unknown elephants to captive elephants could be very stressful and should probably be avoided. However, *technology* enabled us to experiment with digital synthesis of elephant-friendly audio. We subsequently invested a significant portion of our research time into the design and development of acoustic toys that offered elephants control over some of the qualities of the sounds that the toys emitted. We had no idea about what these toys might be like, nor did we initially intend them to be 'instruments', as we started by using audio signals as feedback for interface controls, not as the primary output of the system.

The decision to focus on acoustics solved one problem (what kind of sensory enrichment should be offered) but inevitably produced others. *What kinds of sounds*? *How would an elephant be able to play* with them? *What kinds of controls* could she understand? How would it be possible to *construct* such a device?

In order to find out what kinds of sounds an elephant might enjoy, we needed to offer her a way of controlling the audio output, and we needed to consider how this might be accomplished using simple controls we could make in our workshop. Our subsequent investigations are documented in *Chapter 5: Design and Craft*.

3.4 Insights and Analysis

During prototype production and testing, we experimented with different kinds of evaluation that could be applied to our work. Initially, we identified a subset of goals that could be used to specify each iteration of our design, namely: (i) welfare/enrichment potential (e.g. does it encourage species-specific behaviour?), (ii) collaboration (e.g. teamwork and participatory design), (iii) playfulness (e.g. does it have intrinsic appeal?), (iv) usability (e.g. can an elephant interact with this?), (v) physical manifestation (can we build it?), (vi) technical dimension (e.g. do these sensors work?), (vii) education (e.g. dissemination, impact). These goals could be formally assessed for each intervention, which would potentially generate some qualitative and quantitative data. However, the goals proved to be too rigid as assessment criteria, unable to encompass the wealth of feedback gained from testing each design iteration. For example, we could not assess welfare potential without undertaking rigorous studies of elephant behaviour before and after installing a new device – but since these devices were all rough, experimental prototypes we were expecting to modify, such studies were not appropriate. Similarly, while collaboration was certainly critical for our work, we did not have a suitable scale with which to measure it.

As a result, we looked to RtD for ways of analysing the work and, as mentioned in the previous section, we documented the design and crafting process using *annoted workbooks*. This was a fundamental part of the research, supporting reflection and analysis of the design choices, and giving rise to insights that we have framed within *Chapter 5: Design and Craft* and discussed in *Chapter 6: Reflections on Design and Craft*.

ACI-informed devices are novel artifacts that have come into being as the result of a (usually iterative) design process (discussed in *Chapter 2: Background Research – Design Methodologies in ACI)*. It could be argued that these devices embody the design choices made during their development, although when documenting their work, the focus of ACI researchers has often been on the forms of interaction supported by the artifacts, as expressed by the behavior of the animal users, with the designed objects represented as props in a larger story (Hirsky-Douglas et al, 2018). This is in contrast to the RtD community, whose interest lies more with the artifacts that have been designed, while users play an important role as an 'audience', experiencing and reacting to something new.

We chose to apply RtD design criteria to our research (aesthetic, functional, social, philosophical/conceptual), which informed how we might subsequently present our findings and share some of the knowledge gained.

In the event, with every variation we tried and tested with elephants, there were *insights* gained, broadly relating to: (i) Use of technology, relating to electronically enabled functionality of physical devices; (ii) UX design, which involved trying to appreciate an elephant perspective; (iii) Location, referencing the context and existing environmental features; (iv) Collaborative practice (with humans). Each design therefore informed the next, indicating a positive or negative choice about the subsequent iteration. We have collated these insights in *Chapter 5: Design and Craft* and present an analysis of our collective findings in *Chapter 6: Reflections on Design and Craft*, as well as commenting on the ethical and philosophical dimensions relating to the design of technology for animals. Additionally, we analyse the various methods used or adapted during the project, thereby addressing our final research question: '***What design methodologies would best enable designers to identify and develop the most appropriate designs for such technologies?'***

Chapter 7: Contributions highlights the original work we have done and showcases key aspects of our design approach using a deck of themed cards. Various kinds of cards have been used for ideation and as toolkits for development before (Wetzel et al., 2017; Schell, 2019). Our deck is primarily aimed at ACI practitioners, offering a flexible set of topics for discussion and to support a Research through Design and Craft methodology.

Understanding Elephants

4.1 Understanding Elephants as a Species

The challenge of designing some novel and useful environmental enrichment for a captive elephant requires us to understand the context in which the elephant finds herself. As the primary goal of enrichment is to stimulate natural behaviours, it is important to have a thorough understanding of wild elephant lifestyle.

Building knowledge about the user is part of a user-centred design approach (Sharp et al. 2019) and can also be applied to game designers (Schell, 2019) – designers should understand their audience. With human clients, gathering relevant data can be achieved through verbal or written communication, but data gathering becomes more problematic when the design is for an animal. Fortunately, wild and captive elephant behaviour has been the subject of numerous research projects, so it has been possible to turn to the animal experts for information. As well as referring to academic literature on the topic, interviews have been conducted with a number of people, including Claire Bennett, Head Elephant Keeper at Colchester Zoo, Lisa Yon and other members of the EWG (Elephant Welfare Group), Ally Gillies and Chris Lucas, Chief Research Officer and Head of Large Mammals respectively at Blair Drummond Wildlife Park and Mark Kingston-Jones from The Shape of Enrichment Organisation (SHAPE).

This section describes elephant society and how these animals meet their basic needs. It includes a discussion of elephant cognition and explains in depth how communication enables their lifestyle in the wild. An appreciation of elephant communication and elephant sense-making is vital in order to design an interface for them to use so they can interact with a technically enhanced system. All animals communicate using signals, which can be expressed using different modalities and received using different sensory perceptions. Some of these may be conscious and deliberate, such as a mother offering her trunk to a calf to help it stand up; some may be unconscious and inadvertent, such as the information in a scent left by hormones in urine. Gaining an understanding of these signals may help us to obtain feedback from the elephant users/players when we are testing a prototype with them. As Schulte et al. (2007) state, '*Understanding the relationships and linkage among signal modality, signal function and receiver response is an essential first step before using natural signals for animal care and conservation.'* This point has wider implications: we need to try and grasp the context of particular signals in order to derive some meaning from them in a captive context.

In this chapter, as elephant lifestyle is described, some of the challenges faced by captive elephants are considered, in order to try and pin down aspects of captive life that could potentially be enhanced using playful interactive enrichment.

4.1.1 Elephant lifestyle

Overview

There are three recognised species of elephant – African Savanna (Loxodonta Africana), African Forest (Loxodonta Cyclotis) and Asian (Elephas Maximus). Asian elephants are the closest living relatives to the extinct woolly mammoths, while African Savanna and African Forest elephants diverged in their populations at a similar period in their history (Rohland et al, 2010).

Elephant society is naturally hierarchical, complex and consists of multi-levels of units (Langbauer, 2000). Asian, Savanna and Forest elephants live in matriarchal societies, where the matriarch is usually the oldest female in her herd. According to Elephant Voices (ElephantVoices) '... *older females become "repositories" of social and ecological knowledge'*, thus gaining the respect of their families. Even though they are dominant, daily decisions may be made by other elephants as well.

Elephant society is also matrilineal, in that daughters usually spend their whole lives with their mothers, forming family bond groups from individual family units. All species of elephants seem to operate a fission-fusion society (Archie et al., 2006; de Silva et al., 2011), which means that their groupings are flexible and dynamic. When a herd increases in size (due to more births) and there are more than about six adults, some of the females (usually sisters) may break away to form an associated herd with a new matriarch. These herds form kin-based alliances (Poole Ch. 14, in Short & Balaban, 1994). Males stay with their family until they mature at around 15 years, at which point they disperse and often form associations with other young bulls. Within herds, elephant aunties help rear calves (Lee, 1987; Plotnik and De Waal, 2014), a process known as allomothering. This is one of many examples of cooperative behaviour observed within communities of elephants (Plotnik et al., 2011).

In contrast to this, the lifestyle of captive elephants typically presents a dearth of social opportunities. Elephants in wildlife parks and zoos are usually maintained in herds that are much smaller. Records from the Absolute Elephant Encyclopedia (Elephant E) show that in 2014, there were 15 male and 50 female elephants held in captivity in the UK, distributed among 16 institutions. In 2020, there were 16 male and 38 females in ten institutions. Only Howletts, Woburn, Chester, Blackpool and Whipsnade currently keep herds with more than four animals and many of these groups consist of unrelated elephants. If elephants in the UK were encouraged to breed naturally and form herds with their kin, the rising populations would require more land, but space in zoos and wildlife parks is restricted. Consequently, the opportunities for elephants to live in a natural society with their sisters and aunts, following an older matriarch who is a family relation, are also limited. A report on captive elephant welfare by Harris et al (2008) claimed that this difference from natural herd structure was a cause for concern.

Poole and Granli (2008) comment: '*A [wild] elephant's daily life is distinguished by need, purpose, challenge, choice, will, autonomy and camaraderie*.' It is unfortunate that captivity reduces an animal's opportunity to experience many of these aspects of life. For example, due to the requirement for carefully managed environment, captive elephants don't **need** food because it is always provided. This may impact on their sense of **purpose** in regard to foraging; indeed, there are few of the usual survival **challenges** to overcome. Moreover, occasions for expressing **choice**, **autonomy** and **camaraderie** may be limited. This lack of expressive possibility may even impact the animals' capacity to develop appropriate skills, which is highly relevant for their welfare and display of natural behaviours. While it is clearly beyond the scope of this research to address any missing opportunities directly, our subsequent fieldwork examines the interactions enabled by a social group of elephants in captivity, to see if enrichment could support the elephants to experience some of these behaviours.

Staying alive

Measurement of fitness in animals is judged by their ability to survive, by finding food and avoiding predators, and their ability to reproduce successfully so as to continue the viability of their species (with their own genes). It is widely believed that behavioural and physiological adaptations have evolved because they increase their hosts' fitness, although it should be noted that the traditional Darwinian theory of natural selection has come under recent criticism because it does not explain the complexity of phenotypic traits and their dependence on context (Fodor & Piatelli-Palmerini, 2011).

Elephants have few natural predators, due to their size. However, while human poachers are now their main threat, there is evidence that young African elephant calves have also been targeted as prey by lions and hyena (Salnicki et al, 2001).

Being large herbivores, elephants need to consume vast quantities of food, which means that wild elephants typically forage for 18 hours per day, walking for up to 25 km (Best Practices, 2005) in search of nutrition and water. To survive as a herd and maintain group cohesion in such vast territories, they need to develop good geographical memories and to maintain group cohesion.

Although in captivity, the threat from predators has been eliminated, the restricted space means that elephants typically lack opportunities to exercise sufficiently or map their environment, as they would in the wild. Poole and Granli (2008) identified a number of problems associated with this, including lameness, obesity and arthritis, exacerbated by remaining stationary for long periods. The Elephant Welfare Report (Harris et al, 2008) highlighted the amount of time elephants in the UK have to spend indoors and was critical of the amount of indoor and outdoor space available. '*Smaller amounts of indoor space were associated with increased stereotypical activity … Greater amounts of outdoor space were associated with reduced stereotypical activity and improved gait scores*.' (p.62)

Provision of sufficient space is a dilemma for zoos and wildlife parks. In this regard, our fieldwork shows that different facilities address the challenge in different ways, depending on their available land. We describe enrichment on offer in four different locations - Colchester Zoo in Essex, Howletts Wild Animal Park in Kent, Skanda Vale Ashram, near Carmarthen in Wales and Blair Drummond Safari Park, near Stirling in Scotland.

Reproduction

As mentioned previously, fitness is measured not only by an individual's ability to survive, but also by their ability to reproduce successfully. After male elephants leave their herd, they need to locate females who are not relatives when it is a suitable time for mating. Females only come into oestrus once every four to five years, between calves, and are receptive for one week; there is therefore a small window of opportunity to find an agreeable mate and become pregnant. This can be challenging as elephants' natural range can extend over several hundred kilometres.

Chemical and acoustic signals play a strong part in attracting males to a fertile female and vice-versa. Receptive female elephants are more likely to select a mate in musth, a state that males enter periodically (once or twice a year for several months), when their testosterone levels and associated aggression heightens considerably (Poole & Moss, 1981). They advertise this state to other elephants using a variety of modes (chemical, acoustic, visual) and are much less likely to be challenged by other males, meaning that they can gain access to fertile females without having to fight. This has health benefits since it avoids violence between bachelors and also provides a means for younger elephants to take part in mating – usually an older, larger male would win the right to mate, but a young elephant in musth might be able to defend his territory without too much trouble. (Rasmussen & Schulte, 1998; Schulte, 2007; Poole, 1999).

In captivity, male elephants are likely to be separated from their families at a much younger age, because they are more difficult to look after, particularly when they enter a state of musth. They are often kept in isolation, because not many places have sufficient space to accommodate bachelor groups. This may mean that they lack physical contact with other elephants. Breeding pairs are usually pre-determined by the keepers, because it is important to track family history and avoid in-breeding in the relatively small captive population. In some cases, females are artificially inseminated so that their offspring have wild fathers, in order to keep the gene pool robust (from discussions with Colchester elephant keepers). Wild elephants successfully reproduce more-or-less equal numbers of males and females, but Saragusty et al. (2008) noted the skewing of births in favour of males in captive populations of Asian elephants, as well as a much higher juvenile mortality rate for all elephants in captivity. Ros Clubb from the RSPCA (RSPCA), in a presentation for the Born Free Foundation Compassionate Conservation Symposium (bornfree.org), points out that the low success rate of captive breeding programmes means that the captive elephant population in Europe and US is not sustainable. However, this view has been challenged by Brother Stefan from Skanda Vale, who claims that it is based on out-of-date data and does not take into account the increased longevity of European elephants, as their welfare has improved in recent years. Breeding in the UK and Ireland also showed marked improvements in the last decade (2014: 3 births to Dublin Zoo, 1 to Woburn, 1 to Whipsnade, 1 to Twycross, 1 to Howletts; from EWG Newsletter, Feb 2015). Currently, the most successful elephant breeding facility in the UK is Howletts, whose elephants were responsible for 22 births out of a UK total of 33 up to 2015.

The topic of breeding in captivity is somewhat controversial. Whereas it is commonly acknowledged that giving birth and caring for offspring is highly enriching for mothers and beneficial for all members of an elephant herd, those who do not support the idea of keeping animals in captivity also believe that breeding should be prohibited. At Lakeview Monkey Sanctuary, for example, rescued macaques and capuchins are housed in compatible groups but sterilised to prevent creating more captive animals. As well as being a philosophical stance, this strategy avoids the need to cull excess animals, as space is limited.

One of the benefits of having a successful breeding programme is the increase in young animals around, which in turn results in an increased amount of playful behaviour. Lee and Moss (2014) point out that play is a lifelong activity for elephants, in spite of its risks and energy costs, but nevertheless occurs more frequently in youngsters who often engage their elders in playful behaviour. Playful behaviour that lasts into adulthood is regarded as one of the indicators of a cognitively complex, social animal.

Play

Lee and Moss (2014, p.147) identified the following types of playful behaviour amongst elephants: active solicitation; environmental exploration; object play; lone locomotor play; tactile play; gentle contact and allomothering; escalated contact play and sparring. They found no significant difference between males and females in this regard, except for gentle allomothering play, which occurred between older females and calves, and sparring, which was predominantly between adolescent males. Head-waggling, tusking the ground and curling trunk over tusks were all mentioned as invitations to play. These gestures have also been recorded by Poole and Granli (2008) and can be viewed on their ElephantVoices website (Elephant Voices).

As we have discussed in Chapter 2: Background Research, Burghardt's surplus resource theory (1988) claims that play is more likely to occur when an animal has excess energy; for example, when being cared for by parents and therefore having no need to forage or hunt; when nutritionally replete and not physically exhausted. He suggests that play is therefore likely to occur in captivity because resource demands have been met and animals have surplus energy and surplus time. 'Playful' enrichment is a common addition to elephant enclosures, usually in the form of large objects such as tyres. As an understanding of elephant play is inherent to the design aspect of this project, a significant amount of fieldwork data relates to this aspect of captive elephant behaviour.

4.1.2 Elephant Cognition

Overview

Bates et al. (2008) point out that elephants have the largest brain size of any mammal on earth and that there must be a good reason for this because brains require a lot of energy to maintain. They suggest that the elephant's main cognitive challenges are social, and that their brains enable them to form complex networks and exhibit cooperative behaviours, such as allomothering.

Elephants have been compared with primates and dolphins in regard to their cognitive abilities. Hart et al. (2008) concluded that they could perform as well as apes in many cognitive feats. The measures of cognitive ability they used include determining whether an animal has a 'theory-of-mind', how well they perform on tasks requiring memory, the complexity of their social life, their spatial-temporal understanding. There are other indicators of intelligence, such as problem-solving and tool use, where elephants seem to score lower than apes, although Bates et al. (2008) point out that we typically emphasise these measures because humans excel at solving problems and using tools. It is easier to draw parallels between what a primate does with their fingers and what humans can accomplish with their hands than to compare ourselves to an elephant. Instead, the authors focus on alternative aspects to elephant cognition, such as memory, perception and comprehension.

Empathy and cooperation

Other pointers to an advanced mental capacity are elephants' responses to the death of a conspecific; their reactions seem to show grief, which suggests empathy, which in turn is a prerequisite for an understanding of an 'other' - thus, a sense of self (King, 2013).

Experiments with mirrors add credence to this idea. Plotnik et al. (2009) document a study of mirror self-recognition (MSR) in three adult Asian elephants. The test involved marking the elephants with a white cross on their forehead and seeing how they reacted to observing themselves in a mirror. One elephant behaved as though she understood the mark was on her head, by touching it repeatedly on the first occasion she was given this test. On subsequent occasions, however, she displayed no interest in the mark. The authors point out that the visible change in appearance might be meaningless to a dust-bath-enjoying elephant - apes, by contrast, spend a lot of time grooming. The authors state: '*MSR is thought to correlate with higher forms of empathy and altruistic behaviour*.' They claim that the cognitive evolution of elephants is similar to that of apes and dolphins, because of the stages the elephants went through on their way to recognising themselves in the mirror. These stages were: (i) exploratory behaviour (e.g. the elephants tried to look behind the mirror); (ii) social behaviour, as if the reflection were another elephant (although the elephants did not do this); (iii) contingency behaviour, meaning that they tested the reflection to see if it was consistent (e.g. the elephants repeated certain movements in front of the mirror); (iv) self-directed behaviour (e.g. one elephant tried to look inside her own mouth). They suggest elephants' cognitive development is probably a by-product of having complex social relationships.

Plotnik and De Waal (2014) also assessed the affiliative tendencies of Asian elephants, determining that they expressed consolation towards distressed conspecifics, by mimicking them physically (known as social contagion) and using vocal communication. Bates et al. (2008) found similar evidence of elephants showing consideration for conspecifics, by removing unwanted objects on each other, by helping individuals who had difficulty moving and through the common process of allomothering. They all noted that coalitions might be formed, whereby two or more elephants worked together to threaten or retaliate against another group. Plotnik et al. (2011) demonstrated that '*elephants can learn to coordinate with a partner in a task requiring two individuals to simultaneously pull two ends of the same rope to obtain a reward*.'

Problem solving and learning

Working simultaneously in order to accomplish a task that cannot be done by oneself is a specific kind of problem-solving, which requires an understanding of the other participant and the outcome of their actions. Finding a solution to a challenge also requires insight and demonstrates the ability to learn something new.

Spontaneous novel behaviour is reported as being shown by an Asian elephant in the context of allomothering. Vidya (2014) describes how an auntie elephant dealt with a calf that kept trying to suckle – she gave it her trunk to suck instead of kicking it out of the way, a behaviour that had not been observed before. Another example is provided by Foerder et al. (2011), who provided a young male elephant, named Kandula, with the equipment and motivation to prove his problem-solving abilities, and he did so. Kandula showed insight by spontaneously moving a plastic cube to a position under some branch baited with food, so he could stand on the cube and reach the food. When the cube was removed and replaced with a tyre, he used that instead. The authors believe that this demonstrates tool use and tool generalisation, consistent with insightful problem-solving. They further comment that previous unsuccessful attempts to demonstrate this behaviour in elephants were due to a misplaced emphasis on the trunk as a kind of 'hand' for holding a tool, whereas in fact it is primarily a sensory organ in the context of food. Using the trunk to manipulate a piece of wood to dislodge bait, for example, would detract from its olfactory functionality and also prevent the elephant from using the sensitive tip to best advantage. Using the trunk to hold a branch for fly-switching, on the other hand, has been documented by Hart & Hart (2001).

Memory and categorisation

Studies of the Amboseli African elephants in Kenya demonstrate that they can distinguish between 100 different female elephant calls in their extended families. They also use scent from urine to monitor the locations and identities of conspecifics over time. These skills may facilitate the herd to be mobile and also maintain its integrity.

Elephants can apparently categorise people into subgroups, using olfactory and visual signals. researchers presented groups of elephants with articles of clothing worn by two different tribes - the

Maasai, who occasionally spear elephants, and the Kamba, who do not. Although bad experience with Maasai was limited to a few elephants, the reactions were unequivocal from the group - when they smelled the Maasai clothes, they all showed signs of fear, indicating that some social learning had taken place within the group (Bates et al, 2007).

Indeed, elephants cover huge ranges in the wild, travelling hundreds of kilometers to find waterholes, often along routes that have not been used in several years (Byrne & Bates, 2007). These feats '*suggest exceptional cognitive mapping skills, reliant on the long-term memories of older individuals*.'

Language

Stoeger et al. (2014) state that wild African and Asian elephants have a vocal repertoire of 8-10 different calls which are each flexible and context dependent. Additional vocalisations sometimes emerge in captive situations, where elephants have been documented copying humans and making other unusual noises.

An example of this is the case of an Asian elephant, Koshik, in a Korean zoo, who attempted to communicate with its keepers by making sounds that resembled five Korean words – translated as 'hello', 'sit down', 'no', 'lie down', 'good'. He did this by placing his trunk inside his mouth (Stoeger et al, 2012). Analysis of the fundamental frequencies of the sounds revealed that they were the same as human utterances, but significantly different to natural Asian elephant calls. The authors suggest that this is an example of an animal attempting to cement social bonds across species: '*Convergence of vocal signals as animals become associated is reported for a wide range of birds and mammals*.' In this case, the elephant was socially deprived of conspecifics from the age of five, but heavily exposed to human speech and trained to respond to specific commands.

The paper provides evidence that elephants are capable of vocal perception and also production, which involves decoding the signal they have heard. However, there was little mention of context for any of the utterances. Apparently, Koshik was rewarded every time he made a "human" sound. He was typically stimulated to produce these vocalisations (by his trainer using a set of familiar words), although he sometimes made spontaneous sounds. It is not clear whether the sounds he uttered most frequently ('lie down' and 'good') held any meaning for him, or they were simply the easier ones to reproduce.

Complex communication is one of the hallmarks of a socially intelligent animal and is covered in detail in the following subsection.

4.1.3 Communication

This section summarises recent research on elephant communication, placing it in the context of what we know about communication within and between animals in general.

Overview

The various signals exchanged by elephants in these different contexts (social, reproductive) are part of a complex system of communication between the animals.

According to Mulder and Elgar (*Appendix 2: Professional Development - Coursera, Animal Behaviour 2013),* communication is the 'glue' that holds any society of animals together, whether humans or another species. Modes of communication have evolved in order to increase the fitness of individual animals and, in consequence, their species, by enhancing their ability to find food, escape predators and reproduce successfully. As might be expected, systems of communication have evolved to be more sophisticated in species that live in groups. There are rules for behaviour in social networks, as well as repercussions for transgression.

In species that are organised and spread over a particular geographical terrain – for example, herds of elephants – the animals communicate with each other in order to share resources and manage predators. There are also personal advantages associated with being part of a team, since a particular mode of living together has evolved over time due to its success for the species.

Types of communication vary according to a species' position in the food chain. Hunting pack animals, such as wild dogs, cooperate to find and bring down prey, usually working with members of their own kin (McFarland, 1999, p.118). Foraging animals may share information about the location of food supplies, and some are also known to alert each other to predators. For example, vervet monkeys give three different types of alarm call, depending on whether the predator is an eagle, a python or a leopard. On hearing an alarm, the other monkeys take predator-specific action, which indicates that they correctly interpreted the specific signal (McFarland, 1999, p.484). Similarly, elephants make distinctive alarm calls, depending on the type of threat. Soltis et al. (2014) found that they distinguished between local tribespeople (who dispute with elephants over waterhole access) and African honeybees (whose hives may be located in trees that elephants browse), exhibiting different behaviours and alarm rumbles depending on the threat.

Communication may occur over multiple modalities - visual, auditory, chemical, tactile or electro-sensory. It is said to have occurred when one animal (the sender) gives a signal to another and that signal alters the behaviour of the receiver (McFarland, 1999; Coursera, Animal Behaviour 2013). That is, the receiver must be able to interpret the signal and infer meaning.

Each mode of communication has its own advantages and disadvantages, specifically relating to time, space, subtlety and honesty. If both sender and receiver have a common interest in the honesty of a signal, that signal will usually persist, because it benefits both parties and becomes an evolutionarily stable strategy (ESS - McFarland, 1999, p.93; Maynard Smith, 1982).

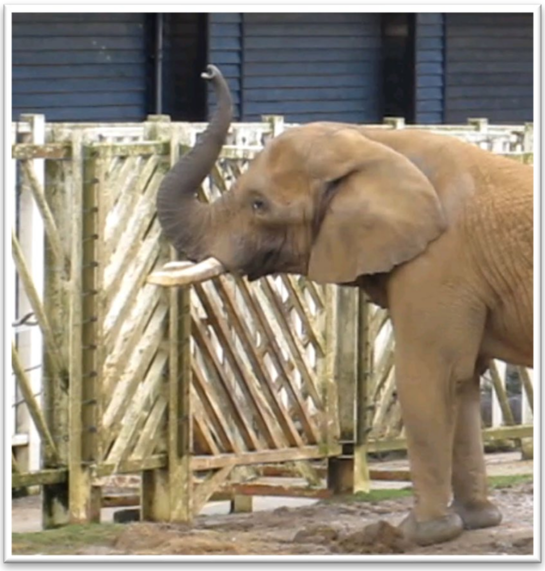


Figure 3: Tembo trunk snorkel, Colchester Zoo (January 2014)

Natural selection is said to favour signals that are loudest and clearest in a particular context, which is one explanation of why different species have such different methods of communication. Animals have developed signals and behaviours that fit specific purposes. Elephants are one example of a species that has seemingly adapted their physiology to their environmental conditions (Poole and Granli, 2008). The elephant's most distinctive feature – its trunk – may be one such example. West (2001) relates recent evidence that manatees and elephants shared a distant aquatic ancestor and suggests that the trunk was originally a snorkel-breathing appendage. Nowadays, the trunk takes a prominent role in all forms of elephant communication.

Visual Communication

Production

Elephant Voices (elephantvoices.org) maintains a large database of visual displays and gestures that elephants make to each other and with each other in social environments, categorised in the following general contexts: (i) attentive (e.g. exploratory touching using trunk), (ii) aggressive (e.g. tusking and slapping with trunk), (iii) ambivalent (e.g. displacement feeding, which resembles foraging but without ingestion), (iv) defensive (e.g. mobbing an intruder), (v) social integration (e.g. affiliative caressing with trunk and ear-flapping), (vi) mother-offspring (e.g. tactile reassurance and suckling), (vii) sexual (e.g. advertisements such as musth walk and urine dribble, courtship gestures such as trunk reaching), (viii) play (e.g. soliciting play with trunk curled on tusk and squelching mud with trunk) and (ix) death (e.g. interventions such as lifting using trunk and tusks, guarding, subsequent investigation of body and bones with trunk).

The propensity to produce such a range of gestures indicates that elephants must also be able to view and interpret these signals, although many of these gestures are tactile and were probably intended to be perceived using touch.

Deliberate visual signals (waving trunk, shaking head, pawing the ground) are momentary and can be thought of as part of a transient conversation between signaller and perceiver. If communication is intentional, it is theoretically possible to lie. For example, the posturing performances by males competing for mating rights are a kind of bluff, which acts as an alternative to fighting and associated risk of injury. Morris (in Mitchell and Thompson, 1986, Ch.11) claims to have observed deliberate deception on the part of Asian elephants in captivity, swinging their trunks in the vicinity of food in order to surreptitiously snatch something edible and faking friendly signals in order to fool other elephants into performing certain behaviours.

Non-deliberate visual signals are typically by-products of other actions or physiological processes. At close range, visual signals can be very clear indicators of intent or fitness. Some appear to be unequivocal, such as the peacock's tail – only a healthy animal would be able to invest so much energy into growing such a spectacularly beautiful feature. This is known as an index signal, which cannot be faked and which persists in time. (McFarland, 1999)

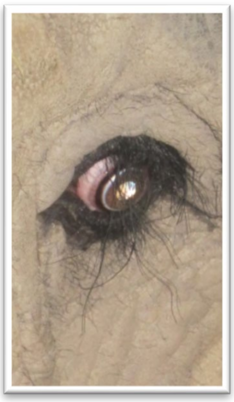


Figure 4: Close-up of Modula's eye, Blair Drummond (Feb 2015)

It might be supposed that tusks would be a strong index signal for the bull Asian elephant, as they are a sexually dimorphic trait. However, Chelliah and Sukumar (2013) discovered that musth and body size override tusk as a male–male signal of dominance, which has important implications for survival, since elephants are poached for their ivory. The number of older male elephants who have grown large tusks has decreased dramatically because they have been the main targets for poachers; in the current climate, it seems likely that elephants with smaller tusks may have a longer life and be able to father more offspring. Visual index signals from males in a state of musth include urine dribbles and gland secretions (these also create chemical signals).

The effective distance of a visual signal is limited by the powers of perception of the receiver, and also by environmental factors, which might block the view. (Coursera, Animal Behaviour 2013)

Perception

There is surprisingly little literature on visual perception in elephants. In a recent paper that examines the composition of retinal cells in elephant eyes, Yokoyama et al. (2005) conclude that it is likely that during the day, elephants can see as well as deuteranopes – people who can distinguish yellow and blue, but not red and green. Nocturnal animals' eyes have big lenses (to converge light), which means they can sense movement in the dark, and a high number of rod cells, which enables night vision. In contrast, diurnal animals (such as humans) have small lenses that offer more depth of focus and project light onto cone cells, which sense different colours. Elephants are arrhythmic animals, which means that they have medium lenses, providing a mix of these abilities, enabling them to see reasonably well during day and night. Yokoyama et al. suggest that, at night, elephants use a combination of rods and cones to detect a different range of wavelengths – something humans cannot do.

Shyan-Norwalt et al. (2009) investigated visual acuity in African elephants and concluded that they can discriminate a gap of 2.75cm about 2m from their eye – in other words, at the end of their trunk. Asian elephants can discriminate a much smaller gap (0.5cm). However, anecdotal evidence from the Elephant Voices site points to the idea that elephants can recognise shapes very well, and that they can determine small changes in another elephant's demeanour from a significant distance – when a human might require binoculars.

Acoustic Communication

Production

Auditory signals are immediate, and then dissipate. The distance that an acoustic signal carries depends on how quickly the waveform attenuates, which in turn may depend on environmental conditions such as weather and landscape. Low frequency infrasound is outside normal human hearing range but it persists over much longer distances than higher frequency sounds and is known to be used by whales and elephants to communicate with conspecifics.

There are a number of good reasons why elephants should have evolved to use infrasound as a medium for communication. Low frequency sound travels along the ground at a different speed from when it travels through the air, maintaining integrity. O'Connell-Rodwell (2007) believes that elephants can detect that the rumbles made by other elephants are different from background noises.

When acoustic waves couple with the earth, the percussive effect is stronger than it would be with an air-borne signal. The power of the signal is related to mass, which is why an elephant can generate

10-20 Hz at over 100 dB. When there are no humans around (for example in the bush), 20Hz is noise-free and therefore makes a good communication channel. The calls made by Asian and Woodland elephants have strong fundamental frequencies and fewer harmonics, compared with African elephants that typically live on the plain. This makes sense because the acoustic propagation of higher frequencies would be dampened by the vegetation in Asian and Woodland elephant habitat. As well as seismic vocalisations, elephants can generate infrasound using their feet. An elephant stomp can travel up to 32km, depending on soil type for attenuation (O'Connell-Rodwell, 2007).

There are many potential reasons for using acoustic communication. Stomping and trunk banging may be threatening behaviours and are highly effective for advertising mood over a wide area, in every direction. All elephants react quickly to seismic alarm signals, particularly if made by familiars (O'Connell-Rodwell, 2007). They typically display behaviours such as defensive grouping, avoiding the area and becoming more vigilant (smelling, scanning, freezing etc).

One way of maintaining group cohesion within a herd on the move is by making contact calls to each other, known as antiphonal calling (McComb et al., 2003). This is a common phenomenon amongst groups of animals; for example, during the breeding season, emperor penguin chicks need to maintain contact with their parents to obtain food and protection, and they do this by calling loudly to advertise their presence (http://www.emperor-penguin.com). Penguins can distinguish their mates and chicks by the sounds they make, and elephants likewise can identify different family members. Leighty et al. (2008) found that elephants used rumble exchanges to reunite with members of their herds if they were separated, but also when they were together. Leighty and Soltis (2007) concluded that some rumble exchanges are communicative events reflecting social bonds, rather than just being automatic responses generated by proximity, but it is still unclear precisely what information is being exchanged.

Soltis (2004) investigated antiphonal calling between affiliated females – a call and response pattern that is frequently used, potentially for the maintenance of the group, facilitation of cooperative tasks and for advertising emotional states. The calls are all distinct, providing clues to identity. McComb et al. (2000) determined that elephants can recognise up to 100 other elephants in their extended families, building up their knowledge as they grow older and encounter more family members.

O'Connell-Rodwell (2007) discovered that female elephants make longer and repeated calls during oestrus, which facilitates detection (by distant males) by reducing the interference of background noise. This ia achieved by making both seismic and acoustic signals stronger. Elephants can probably also detect the distance between themselves and another calling elephant (Leighty et al 2008).

Perception

O'Connell-Rodwell (2007) analysed various mechanisms that could potentially be used by elephants to send and receive seismic signals, from physical, behavioural, anatomical and physiological perspectives. She concludes that vibration is a multimodal signal, as it can be both felt and heard.

Elephants have a large diaphragm, and five bones in their larynx (humans have nine). This facilitates the production of loud rumbles.

They can detect infrasound through both bone conduction and via somato-sensory perception. Their inner ear has an enlarged malleus, which provides a bone-conducted pathway for seismic signal detection. Elephants can occlude the opening of their ear canal, potentially building pressure in the air canal to enhance bone conduction. In addition, they possess an aerated skull and sinuses, and fatty deposits which may act in a similar way to acoustic fat in dolphins and manatee – facilitating low frequency detection. Elephant foot fat does not deplete in winter, and also seems similar to acoustic fat, protecting the foot bone and enhancing rather than dampening acoustic signals.

Figure 5: Trunk tip, African elephant, Colchester Zoo (2014)

Elephants also possess somato-sensory and cutaneous sensory organs that might be mechanoreceptors - Pacinian corpuscles (which respond over a large area to vibrations and changes in pressure) and Meissner corpuscles (which respond to dynamic changes and are used for motion and grip control). Both types have been found in the Asian elephant trunk tip, and Pacinian corpuscles in the toes and heels of elephant feet (which may be why they lean forward or back to listen). '*The ability of touch receptors to discriminate very small changes in frequency (2 Hz) has been demonstrated in humans and other primates. It is likely that elephants have at least the same vibrotactile frequency discrimination abilities as primates, if not better*' (O'Connell-Rodwell, 2007).

Leighty et al. (2008) suggest that because they use both feet and ears to detect seismic information, this enables elephants to determine how far away a sound is being made. Their inner ear distance is only 0.5m, but toe to ear is 2.5m, which is a better phase difference for determining direction and distance of frequencies at around 20Hz (which has a wavelength of 17m). When elephants hear an alarm signal, they lean forward so their front feet are in line with their ears. This is believed by O'Connell-Rodwell (2007) to enhance bone conduction. Sometimes they lift a front foot, which may facilitate triangulation for localisation of sounds (foot to ear to ear).

There is evidence that elephants are highly aware of their environment via their sense of hearing, not only paying attention to conspecifics. It is likely that they can perceive distant thunder and be able to anticipate storms; King et al. (2010) found that they produce a distinctive alarm call in response to the sound of bees, which they fear.

Tactile Communication

Production

Tactile signals are thought be honest indicators. They can be part of an aggressive manoeuvre, signalling the relative strength of participants, as when rams lock horns. They also form part of the parent-offspring bond in mammals, during suckling and play. Elephants use their trunks to touch each other, as well as sometimes using their bodies to barge neighbours out of the way. Many of the visual gestures described in the Elephant Voices database fall into this tactile category and are more likely to be perceived as tactile signals by the recipient.

Trunks can deliver slaps as easily as caresses. Photographs of a selection of tactile gestures are shown in the next section: *Ethnographic Study: Understanding Elephants in Captivity.*

Perception

Rasmussen and Munger (1996) analysed the sensorimotor specialisations in the trunk tip of the Asian elephant and concluded that it is a very sensitive apparatus: '*The unique sensory innervation of this specialised region of trunk (tip) resembles lip tissue of monkeys or mystacial skin of rodents – this correlates with the tactile ability to grasp small objects and insert chemically active samples into the ductal orifices of vomeronasal organ for chemosensory processing*.'

Hoffman et al. (2004) examined primates and elephants for evidence of cutaneous mechano receptors of the types found in humans. They detected increased resolution of Pacinian Corpuscles, hair-cells with Merkel terminations (for perception of form and texture), free nerve endings and some multi-branched corpuscle receptors.

Martin and Niemitz (2003) found that Asian elephants are typically 'right-trunkers' or 'left-trunkers', which adds to the notion that the trunk can be compared in some ways with a human hand – it is used for caressing, feeding oneself and others, investigating novel objects and manipulating tools. The fact that a trunk is also simultaneously a nose and a sound producing organ greatly increases its utility.

Chemical

Production

The most honest signals are thought to be chemical, perceived by olfactory senses (Maynard Smith, 1982). Chemical signals are usually involuntary, so the signaler cannot disguise the message. For example, the hormones produced by female mammals at particular times during their oestrous cycle are reliable indicators of the animal's fertility. It makes sense for natural selection to favour honest signalling in this context, to ensure that the male does not waste his energy on non-viable procreative activity and that the female always attracts a mate when she is ready to reproduce.

Plotnik et al. (2013) found that elephants used olfactory cues but could not use auditory clues to find food. Both male and female elephants produce chemicals that signal their reproductive state. Males in musth excrete from their temporal glands, which acts as both a chemical and a visual index signal. All elephants produce chemicals from glands in their ears, anal region, mouth, eyes and in their urine.

Chemical signals are immediate but may also persist for hours or days or months, so that delayed communication is possible. Their range is both near and far, depending on the senses of the perceiver and external factors such as humidity and wind. In many situations, chemical signals act as cues, because they are not direct and in real time. Cues are information embedded in the stigmergy (self-organisation) that can be read and reread many times by different members of the species, such as scent trails left by foraging ants. Stimergic organisation is indirect and distributed, allowing simple individuals to coordinate their activities so that complex structures emerge (http://en.wikipedia.org/wiki/Stigmergy).

Perception

Elephants initially use their trunks to smell the world around them. The human sense of smell is very poor compared with most other animals, so it is hard for us to imagine the richness of the world of scents, which gives information about historical activity, a feature that is hidden from us. With vision, we perceive the current moment as it happens. Any deductions about previous events must be inferred, whereas a dog or an elephant, for example, can probably determine what we ate for breakfast from the smell of our clothes. When a dog or an elephant goes for a walk, the world is full of dissipating scent trails that we do not perceive or understand.

Elephants have a large vomeronasal organ situated in the roof of their mouth. In order to perceive a scent in more detail, they may flehmen, which involves sniffing the scent sample with their trunk (which uses the main olfactory system, like a nose in humans) then placing the trunk tip into the mouth to access this special organ. Chemical signals can also be detected using taste (Langbauer, 2000; Schulte et al, 2006).

Plotnik reported on a study ('Thinking with their trunks', 2014) that aimed to find out which senses were more useful to an elephant performing cognitive tasks and concluded that they may use olfactory cues over acoustic cues. The experiment offered the elephants two choices, rewarding (food) and non-rewarding (not food), and provided cues to see if they could use them to discriminate between the choices. Their sense of smell allowed them to determine which option to take in order to obtain food, whereas they were not able to make the correct choice when using their sense of hearing. However, it is important to note that elephants would naturally use their sense of smell to make decisions about what is edible and where to find it, rather than their sense of hearing. It is more likely that they would use their sense of hearing to determine the location and identity of a herd member, for example, so it seems premature to link olfaction more strongly than acoustics to cognition.

Plotnik (2014) expresses the importance to welfare of trying to perceive the world from an elephant's point of view: '*If elephants primarily interact with the world using their non-visual senses, the 'human perspective' for solving conservation problems will not be enough. The more we understand about how elephants navigate their physical and social worlds using non-visual sensory modalities such as sound and smell, and how their behaviour continues to adapt to ever-changing threats, the better able we will be to effectively work to protect them in the wild*.'

Summary

The following table summarises this part of the chapter by offering a comparison between different modes of communication with respect to proximity, duration, honesty and purpose.

Table 1: Comparison of modes of communication in elephants

MODE	ACTUATOR	SENSOR	PROXIMITY	DURATION	HONESTY	PURPOSE
Tactile	Body, trunk	Touch (using trunk and whole body)	Close range	Immediate	Yes, but bluffing possible	Attentive (determine state of mind and health), aggressive (displays of dominance – barging and stealing food), ambivalent, defensive (group mobbing), social (bonding), maternal (caressing, sheltering), sexual (tail-holding, mounting), playful (tug-of-war, trunk wrestle) and investigatory in death.
Visual	Body, trunk, ears, legs, glands	Sight (using eyes)	Limited spatial range	Immediate	Yes, but bluffing possible	All tactile signals can be perceived at close range. Some visual signals are involuntary (urine dribbling and gland secretions in musth and oestrus); some can be seen from afar (musth walk).
Acoustic / vibration	Trunk, legs	Hearing / touch (using ears and feet and bones)	Infrasound – several km; higher pitch much closer	Immediate, dissipates quickly	Yes, but bluffing possible	Clear signalling of identity, distance, emotional state, for group cohesion (antiphonal calling), bonding, calling for help, expressing anger and fear (alarm calls), repeated calling to signal fertility. There are other contexts and we do not understand all the signals.
Chemical	Various glands, urine, rectum, feet, mouth (saliva), temporal gland	Taste, smell (using trunk and mouth)	Near and far – 500m	Immediate and delayed	Yes	Signalling fertility; eg. musth in males and oestrus in females. Trail-marking; signalling state of mind (eg. level of anxiety), potentially state of health and recent diet.

4.2 Ethnographic Study: Understanding Elephants in Captivity

During 2014 and 2015, we were able to conduct fieldwork with elephants whose carers allowed the author to observe them closely and also ask the keepers some questions. In doing this, we aimed to address questions relating to environment, enrichment, behaviour and, in particular, play:

- How do different institutions address the problem of providing sufficient indoor and outdoor space for their elephants?
- What kinds of enrichment are currently being offered?
- How do captive elephants behave towards each other in their groups?
- What are some of their interactive behaviours?
- What kinds of play take place in captivity?

From January to April 2014, the author visited Colchester Zoo on a regular basis and made extensive notes on the behaviour of their elephants (see *Appendix A6: Ethnographic Data*). Photographic and video reference material was collected. A visit was made to Howletts Wild Animal Park during this period, for a comparative study. In October 2014, a visit was made to Skanda Vale Ashram for two days to meet their elephant and discuss ideas with keepers; a similar visit to Blair Drummond Safari Park was conducted in February 2015.

In August 2014, the author also undertook a four-day course in environmental enrichment, summarized in *Appendix A5: SHAPE SEEC*.

4.2.1 Introduction to the elephants

In each case, the elephants' circumstances were different – their varying histories, environments and personalities ensure that 'one size fits all' does not apply.

Figure 6: Opal and Tanya at Colchester Zoo (Feb 2014)

Figure 7: Tembo and Zola at Colchester Zoo (May 2014)

Colchester Zoo, in Essex, keep four African elephants, separated into two pairs in different adjacent enclosures – Tanya (the matriarch) stays with Opal (also female) in one paddock; they are FC (full contact) elephants, whose keepers walk with them and wash them daily. In the adjacent paddock resides Tembo, the bull, who regularly enjoys the company of Zola (female); they are both *protected contact* elephants, which means that keepers must administer to them from the other side of a fence and never be in the same space. The two elephant paddocks are in close proximity, so the animals can hear and smell each other. None of the elephants are related. Zola and Tanya were both wild born; Tembo and Opal were both raised as circus elephants. They all range in age between 30-40 years.

Figure 8: Valli goes for a walk with Brother Stefan (Oct 2014)

At Skanda Vale Ashram, near Carmarthen in Wales, there was one Asian temple elephant, Valli, who was raised by hand from the age of four months, having been orphaned in Sri Lanka and donated to the monastery. She had not experienced the company of other elephants since arriving in the UK in 1981, but she has always been *full contact* with her keepers and other members of the community. Since the ethnographic study, Valli has been joined by another Asian female, a rehomed circus elephant.

Blair Drummond Safari Park, near Stirling in Scotland, kept two female African elephants, Mondula (the matriarch) and Toto (who died in 2016). Mondula behaved as if Toto was part of her herd, but according to keeper Chris Lucas, Toto didn't understand how to be an elephant – she was subservient but treated Mondula as a different species companion animal; historically they were both rescued from other animal shelters where they had been reared in isolation from elephants. Both elephants were *protected contact*.

Howletts Wild Animal Park, in Kent, currently maintains a herd of thirteen African woodland elephants in an extended family grouping, with the most recent arrival being born in 2019. According to Howletts, their elephants are *no contact*, although they must have had some training in order to understand which barn to go to in the evening.

Figure 9: Mondula at Blair Drummond Safari Park (Feb 2015)

Figure 10: Some of the Howletts herd browsing wood

4.2.2 Environment

The three places the author visited in a researcher capacity (Colchester Zoo, Skanda Vale Ashram and Blair Drummond Safari Park) all provided excellent indoor facilities for their elephants.

The new elephant shed at Skanda Vale featured in Green Building magazine, Vol 24, No.2, as an exemplar of best practice in sustainable design.

Figure 11: Elephant barn at Skanda Vale (Oct 2014)

Figure 1: Pool inside barn at Skanda Vale (Oct 2014)

The shed has sandy substrate and also a padded flat floor, for Valli to lie down on to be washed. There are 2 doors, one of which can be opened form inside, leading to a paddock with an electric fence. The other can only be opened by a keeper and leads to the exit when Valli goes for walks. There is a small pool with a waterfall and a fenced area which has access to the corridor outside, with bars wide enough for people to easily access. There are 2 heated walls, pipes set in concrete, with a wood-fired boiler and large insulated tank. The space has plenty of roof lights. A balcony overlooks the shed and there is also living accommodation for the Swamis who look after Valli.

Figure 13: Mondula inside Blair Drummond barn (Feb 2015)

Chris Lucas, Head of Large Mammals and elephant keeper at Blair Drummond Safari Park, won a best paper award at the annual Regional Environmental Enrichment Conference (2014) for his report on elephant enclosure design, with an emphasis on providing control for the animals. Mondula and Toto had continuous 24-hour access to their outdoor paddock, via a flap door. Their spacious shed had a variety of different spaces so they could choose whether or not to be together.

At Colchester Zoo, the indoor enclosure is divided into different areas – personal and communal. The *full contact* elephants have access to the communal area, which is equipped with a variety of feeders and large toys. Public viewing is possible via large glass walls. The *protected contact* animals have their own quarters but no access to the communal space, as the elephants are not on friendly terms.

Figure 14: Tanya and Opal inside Colchester Zoo elephant barn (Mar 2014)

During the visit to Howletts Wild Animal Park, we were able to view the open shelters in the paddock area, but not inside the night-time sheds. The temperature in March (2014) was sufficiently cold that the elephants were keen to go back to the sheds at the end of the day, the smallest ones at the front of the queue to pass through the gates.

Figure 15: Valli scrambling up the hillside (Oct 2014)

Of all the elephants kept in captivity in the UK, Valli at Skanda Vale certainly has the widest outdoor range to explore. Although her enclosure is a similar size to other zoos and safari parks, she is taken on daily walks around the 115 acres of woodland, hills and meadow that surround the ashram. During the visit in October 2014, she stayed with Brother Stefan for much of the walk along a forest path until we reached an

Figure 16: Valli wandering though woodland (Oct 2014)

open part of the landscape, when she left us to forage on the hill. The author had not witnessed an elephant voluntarily and freely scrambling up and down slopes before.

Elephants at Colchester are separated into two large paddocks, which are partitioned from each other by a row of trees and bushes and from the public by a dry moat, so that there are clear views of the two female FC elephants, Tanya and Opal, while Zola and Tembo are hidden from visitors (although we were given permission to visit as part of our ethnographic study). Both paddocks have small pools with fountains and a small amount of shelter/shade from rain or sun. The substrate is soil and clay, so that muddy holes can be delved when it rains and dust baths are possible in the summer. The land slopes slightly upwards. The distance from one end of the paddock to the other is about 100m.

At Blair Drummond, the paddock is a similar size, flat and dotted with features such as bushes and arches. The Howletts herd have a 100m paddock with covered sheds, access to a 50m x 200m meadow and also a large barn area as big as their paddock.

When we discussed the provision of novel enrichment with the elephant keepers, they all seemed to prefer the idea of providing novel enrichment inside the barns. At Blair Drummond, Chris explained that it was important for visitors to keep the outdoor enclosure looking as naturalistic as possible – in other words, without a manufactured computer interface being visible – but another reason is that the elephants typically spent a lot of time indoors during colder months and this would be the obvious place to give them extra stimulation. Outside, the elephants were free to roam and browse within the limits of their enclosures, but inside, the environment was currently regulated by the keepers, who would like their elephants to have more autonomy. Another more practical reason is that there are few electrical sockets around the enclosure. However, even though a device might work from a battery, it would still have to be weather-proof in order to be situated outside. Finally, from the point of view of safety, Chris and Brother Stefan both recommended locating a device on the other side of a strong wall to help to protect it.

4.2.3 Provision of enrichment

As a result of health problems associated with lack of exercise, enrichment for captive elephants often aims to encourage exercise and foraging behaviour within the confines of the enclosure, by distributing food widely and using puzzle feeders to restrict access, requiring the animals to search, stretch and use their trunks. At Colchester Zoo for example, keepers scatter treats (cabbage leaves, carrots) around the periphery of the enclosure before the elephants go outside in the morning. Fresh browse (hay) is placed in different locations throughout the day so the elephants have to move around to access it. In addition, Colchester Zoo operates an 'elephant feeding opportunity' for visitors twice a day. Tanya and Opal know when this is going to happen and independently make their way down to a metal gate, where the author observed them doing some stereotypic behaviour while they were waiting, including head weaving and turning full circles. Visitors can manually offer the elephants a small piece of vegetable.

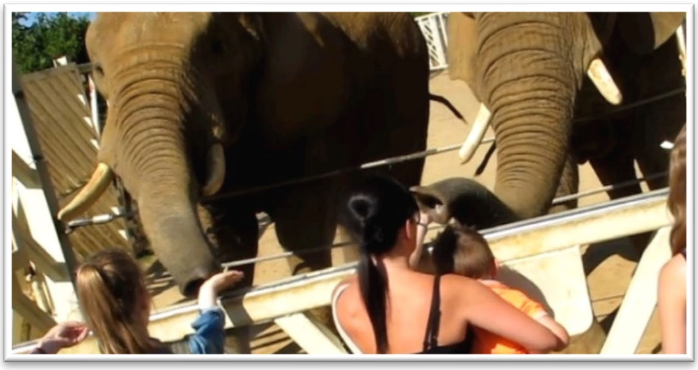


Figure 17: Feeding time at Colchester (Aug 2013)

While Valli's visitors are similarly encouraged to offer her a piece of fruit or vegetable, she has many opportunities to roam and browse at Skanda Vale. Valli takes three walks a day, with the afternoon outing usually at least three hours long. When the author accompanied her on one of these treks with her keeper, Brother Stefan, Valli repeatedly attempted to stop and eat grass and leaves. Brother Stefan said that in October, the nourishment in grass is limited, compared with spring grass, which is full of nutrients. He regularly stops her from eating and offers encouragement as well as gentle slaps in the preferred direction, because the idea of the walk is to give Valli exercise, and therefore she must work to reach a meadow where she can stop and forage. She likes willow and broom, sometimes brambles. She is permitted to wander freely and easily walks downhill and uphill, off-track and into scrubland.

Figure18: Valli foraging on walk at Skanda Vale (Oct 2014)

The Howletts herd are provided with fresh branches and twigs every day, and they can forage in their meadow. Blair Drummond elephants also have forage supplied in different locations at regular intervals throughout the day. In every case, the elephants are supplied with hay in their overnight sheds.

Figure 19: Young elephants play with tyres at Howletts (Mar 2014)

At Howletts, the paddock had some suspended tyres that were used vigorously by two young elephants, charging them for target practice. There were also large logs for elephants to clamber over, but by comparing the elephants' behaviour with video footage of wild animals, we concluded that the best enrichment of all was the company of other elephants. The herd seemed well integrated, in that no elephant was marginalized and they stayed loosely together. There were continuous interactions between all the animals. Colchester and Skanda Vale also provide tyres for the full contact elephants indoors.

When the author spoke to the elephant keepers at each institution, they were keen to provide new environmental enrichment for their animals and had several ideas. The Colchester team had hopes for a boomer ball, which is a very large, indestructible ball designed for animal enrichment, and a wobble tree, which is essentially a pole buried deep in the ground with tyres so that it can be bashed without snapping. They also mentioned showers that the elephants could control themselves. At the time (February 2014), these items were all dependent on the available budget. Keepers at Blair Drummond and Skanda Vale were very enthusiastic about providing more choice and control for their elephants; controlling showers has emerged as a common theme amongst the elephant keepers, as well as possibly being able to modify heat and light inside the barns. Chris Lucas was keen to provide shower controls, because his elephants avoided showers that were activated by the keepers (they moved outside immediately) and he wanted to see if they would lose their reluctance when they could control the showers themselves; Brother Stefan knows that Valli enjoys rain and bath-times and thinks she would enjoy being able to activate her own shower.

4.2.4 Overview of behaviour

Most of the recorded observations have been of the Colchester elephants, who were visited regularly over a period of three months. On each visit, the author spent 1 hour at each paddock, noting both sets of elephants' activities at 10-minute intervals, as well as making sketches and taking photos and videos. A snapshot of the data is presented in *Appendix A6: Ethnographic Data*, and a summary is shown in Table 2: Summary of Elephant Behaviours. We were particularly interested in what elephants do when they are not foraging because our aim is to devise some enrichment that is not related to food but is motivating because it is cognitively stimulating and is its own reward.

The data is organised into a range of different activities, categorized as follows: (i) Food related; (ii) Social; (iii) Playful; (iv) Stereotypic; (v) Keeper-oriented; (vi) Bodily function; (vii) Acoustic. Some activities, such as Tanya barging Opal out of the way in order to be first to access the hay, belonged to more than one category (i and ii).

It was also noted which elephants performed each activity, and which part of the elephant was being used (body, legs, trunk, ears, tusks, head, tail) so as to have an idea of how much exercise they were doing. This snapshot of elephant life indicates the range of behaviours amongst particular elephants. Many other factors, such as weather, time of day and time of year could have had an influence on the data and a longer study would be required to gather information about frequency of behaviours.

All the elephants were observed foraging, standing close to each other, smelling each other's faeces and head-weaving for short intervals.

Valli at Skanda Vale had the company of Brothers Peter, Stefan and Danny. Her excursions with them seemed to be her major form of enrichment, as well as shower times. Howletts elephants appeared to be living in naturalistic groupings and enjoying each other's company. The keepers told me that there is a lot of frolicking in the meadow during the warmer months and described how much fun it is to watch the younger elephants playing.

The immediate impression was that the elephants were strongly interested in all the smells in their surroundings. The Colchester elephants regularly performed a 'periscope' trunk to detect source and nature of scent in the air; all elephants investigated items on the ground and in crevices with their trunks, which would give them tactile and chemical feedback; the dominant elephants in the Colchester pairs used their trunks to smell their partner's scent marks and subsequently inserted their trunks into their mouths to obtain a stronger signal from their vomeronasal organ. Using their trunks to organise, browse and interact with the environment was an obvious trait for all the elephants, and it would therefore make sense to design an interface that elephants could interact with using these appendages.

Table 2: Summary of elephant behaviours

Type	Activity
Food-related	go into pool; weave head; walk to hay spot; scoop hay from pile; sweep trunk over ground; pick stuff from rocks; pick up dropped food; take food item from visitor; nudge conspecific out the way; smell/touch other inside mouth; walk to lower gate; walk round pool; walk to wall; walk to boundary; walk to top field; clamber up over rocks; trunk through fence; periscope trunk; graze over fence (grass); hold clump of hay and select bits; drink from pond; drop food; find cabbage etc after feed time; smell hay before eating; shake mud from hay before eating; walk in circles
Social	nudge conspecific out the way; smell/touch other inside mouth; caress trunks; tusks together, facing each other; stand together; hold other tail; snort; trumpet; smell poo; smell/touch other genitals; smell/touch other ears; smell/touch other top of head; smell/touch other eyes; smell/touch other back; follow another elephant; back away; shake head and ears
Playful	caress trunks; tusks together, facing each other; go into pool; flop trunk over tusk; investigate muddy hole; dig mud with foreleg; head into mud; spray dust on self; spray mud on self; pick up large stick; raise two legs
Stereotypic	weave head; walk in circles
Keeper-oriented	follow keeper; lift feet for keeper; lift trunk over head (periscope)
Bodily function or other reaction	do pee; do poo; avoid walking on poo; flap ears; feel ear with trunk; feel tusk with trunk; feel own eye with trunk; feel back with trunk
Acoustic	snort; trumpet; raise one leg

Figure 20: Tanya keeping straw on her tusk (May 2014)

The social hierarchies were evident when food was available. Fresh browse added to the enclosure attracted both elephants, but Zola, the female, waited to one side until Tembo, the male, had selected some food and then she gradually approached. First of all, she picked up straw he had dropped on the ground, then she reached for some of the fresh pile herself. Both Tembo and Tanya (the bosses in their respective paddocks) have developed a habit of stuffing a pile of straw on one of their tusks and walking around browsing from this. Tanya was observed shoving Opal out of the way when she wanted to access a pile of straw, even though she could easily have moved round her partner to reach it from the other side. Valli has no competition for food, but she has clear expectations about when she will receive treats and from whom – keepers and any visitors. At Howletts, the smallest calf sheltered under its mother near the fence when all the elephants were selecting pieces of wood to eat. Older siblings or cousins (still small elephants) pushed forward to access the wood and the smallest one retreated quickly out of their way.

It is reasonable to assume that these hierarchies exist in multiple contexts, so any new device introduced to a shared enclosure might also be dominated by one of the elephants if it was popular. Claire Bennett at Colchester confirmed this, suggesting that Tanya would coerce Opal into doing the work, but immediately take all the reward for herself (if the system provided food). One of the issues that potentially arise with an acoustic device is that the output affects everyone in the vicinity, and one elephant's enrichment might be another elephant's stressor. We noted that these aspects would have to be taken into consideration, particularly when using sounds. We have to be careful not to introduce unnecessary competition.

4.2.5 Playful behaviour

The following sections are based on Lee and Moss' categories for wild elephant play (2014).

Soliciting play

During our time conducting fieldwork at Colchester Zoo, the author noticed Tembo, Zola and Tanya performing the trunk-curl-over-tusk movement that is indicative of a play request, according to the Elephant Voices gesture database analysis (http://www.elephantvoices.org/multimedia-resources/elephant-gestures-database.html). In Figure 22, (still from video) Tembo performs this action and Zola comes towards him; he then slowly reaches up and strokes her on the head, after which she retreats.

Figure 21: Tembo does trunk curl (March 2014)

Opal and Zola were both keen to tusk muddy ground, but as there were no other elephants around, we interpreted this to be a form of individual locomotor play and environmental exploration rather than a solicitation. The young elephants at Howletts were very playful with each other, but the author did not notice any specific gesture associated with a request to play.

Environmental exploration

All the elephants investigated their environments. We believe this experience was probably richest for Valli, with her acres of hillside and woodland, as there would inevitably be lots of new animal scents every day, and also each walk might cover different areas. At Colchester, there were lots of rabbits sharing the elephants' paddocks, as well as birds who frequented the pools and scavenged for seeds amongst the browse. These would provide novel natural scent trails, but most of the exploratory behaviour seemed (to the author) to be associated with finding food.

Object play

Zola was the only elephant in the Colchester group who seemed interested in playing with sticks but Tembo and Tanya both spent some time sticking bunches of hay on their tusks and walking around with them. This may have been to ensure that the subordinate elephant in the enclosure did not access the food, but it happened when there was plenty of other hay lying around. At Howletts, some young elephants spent a lot of time tusking a large lorry tyre that was hanging in the enclosure. We were told that Valli, at Skanda Vale, used a branch in her shed to reach through the bars and smash up a sink unit three metres away – whether this was playful or an act of aggression or simply a call for attention is unclear.

Lone locomotor play

Watching Opal wallowing in a self-made mud-pit at Colchester was a fascinating experience, demonstrating both locomotor and tactile play. Although there are practical reasons why elephants like to be covered in mud (to protect their skin), her lengthy and sensuous interaction with the mud seemed to be performed purely for pleasure. Tanya and Opal are showered by the keepers, usually in the morning inside the barn. This involves a lot of interaction between keepers and elephants, who have a temporary chain on their legs to stop them from moving away. The elephants' feet and ears are checked during this procedure. As soon as they are allowed to go outside, they make their way to the top part of the paddock and proceed to spray themselves with mud (this happened on multiple occasions).

Figure 22: Opal enjoys mud (March 2014)

Zola also spent some time excavating a muddy hole, and was down on her knees in it, but none of the other adult elephants rolled around as much as Opal. One of the youngest calves at Howletts also spent some time rolling in a muddy part of the meadow, near his mother. Tembo did not seem interested in mud-play.

Social play

Tembo and Zola demonstrated a lot of tactile play *with each other*, including trunk wrestling, according to their keepers (although we did not witness this particular activity). Tembo appeared to be the main instigator of tactile play with Zola, in that he was always the one reaching out and touching her. However, if he was standing alone for any length of time, Zola would approach him without touching and perform a bodily function close by, as if making a deliberate chemical signal. He would then be aroused to smell the deposit and start to follow her again.

Our observations of Zola and Tembo lead us to conclude that having a degree of arousal and contact with a member of the opposite gender is highly enriching for elephants – but only if it is an elephant they like. It seemed clear that these two animals enjoyed each other's company, an idea confirmed by Head Elephant Keeper Claire Bennett. We subsequently discovered that the pair had mated before, but Zola had been unable to carry a calf to full term. Claire said that Tembo and Tanya (the matriarch) did not get along. When Zola was with the other two females, she was the most subordinate elephant, and bullied, which was why she was moved to be with Tembo, previously on his own.

Tanya and Opal, meanwhile, often remained close together, but were not as tactile with each other. In each pairing, the author only observed the two dominant animals, Tanya (the matriarch) and Tembo (the male) barging their partner out of the way. The Blair Drummond elephants, Mondula and Toto, had not bonded, as explained earlier.

Gentle contact and allomothering

Valli enjoyed some gentle play-fighting with Brother Stefan, but only using the tip of her trunk, when he was on the other side of a wall. The contact between the Colchester elephants was always gentle when the author was there, but the kind of play that Moss and Lee (2014) describe occurred only within the Howletts herd, who had several juveniles.

Figure 23: Zola and Tembo, tusk wrestle (Mar 2014)

Figure 24: Zola and Tembo, caress head (Mar 2014)

Figure 25: Tembo caress Zola's head (Mar 2014)

Figure 26: Zola performing trunk curl over tusk with Tembo (Mar 2014)

Escalated contact play and sparring

This kind of play was most evident in the Howletts herd. The young and adolescent elephants spent a lot of time squaring up to each other and barging each other around. One young elephant barred the walkway to the meadow for about 20 minutes, flapping ears and doing mock charges at another young elephant who was trying to pass by. The play-fighting took place between elephants who were roughly the same size/age, including some of the young adults.

While much of the obviously playful behaviour happened between elephants sharing a space together, there was a lot of exploratory behaviour that involved smelling and touching surroundings. We think it would be a missed opportunity if an elephant toy or game did not incorporate a tactile element, as all elephants seemed to find this interesting. It will not be possible to construct a large toy sufficiently robust to withstand the full strength of an elephant within the scope of this work – such as the Howletts swinging tyres – but we could still design an interface that provides haptic feedback, possibly accessible only via a trunk tip.

4.2.6 Themes emerging from observations

It became clear that captive elephants in the UK are not a homogenous group. Quite apart from being different species (African and Asian), they all find themselves in unique situations. Some have *no contact* with their human keepers; some have *protected contact*, where the keeper is always on the other side of a barrier, while there are yet others who have *full contact*. The majority are housed with at least one other elephant, although there are exceptions. Many animals are kept with conspecifics who are not their immediate family and very few have the experience of being part of a herd. The elephants we studied during this part of the fieldwork are representative in that they too were all handled differently and lived in a variety of social conditions. In addition, we observed both species of elephant – African and Asian.

There were other aspects to elephants that marked them out as distinct individuals – their interests and attitudes. Even when elephants were housed in similar conditions, their behaviours varied, as evidenced by the different ways in which they played.

Elephants kept in traditional urban zoos seem to have similar enclosures, comprising yard and barn, while those fortunate enough to be housed in the countryside might have access to meadows for grazing. In most cases, access to different parts of the enclosure is controlled by the keepers and managed according to a fixed schedule. The elephant is not in charge.

All keepers were concerned about their elephants becoming bored during winter months, when they are housed indoors for long periods (because of the cold). The barns all contained enrichment opportunities in the form of browsing bays and large objects (tyres) to play with, but no-one is attempting any acoustic enrichment yet. It is worth noting that zoo staff are also busier during summer, so colder times might be optimum for introducing novel enrichment and asking people to participate in its development.

4.2.7 Summary – Experience gaps

One of the goals for this fieldwork was to identify how life for captive elephants might be different from life for wild elephants, so as to identify any experience gaps that could be filled with enrichment. We addressed this in terms of the elephants' expression of behaviours. This gave rise to two questions:

- How does captive elephant behaviour differ from wild elephant behaviour?
- What aspects of wild elephant behaviour appear to be missing from the repertoire of captive elephants?

Clearly, elephants such as Valli are missing out on all social opportunities with other elephants and the other elephants' social lives are limited by comparison with wild herds. Because of their complicated backgrounds and the fact that some have been raised in captivity and others not, it is impossible to identify any single behavioural feature that they would all benefit from experiencing. However, we identified the following aspects of wild elephant behaviour that seem to be missing from the experiences of many of the captive animals visited, with a view to potentially addressing these gaps in the context of enrichment design: (i) Antiphonal calling (call and response); (ii) Long distance navigation; (iii) Nowhere for matriarch to lead – not enough decisions to make! (iv) No allomothering (if no calves).

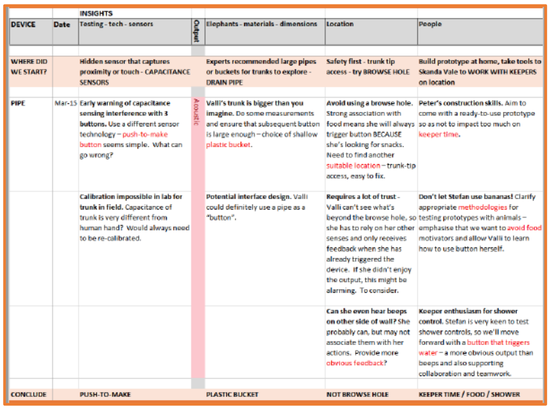
Antiphonal calling relies on elephants recognizing who is making the call and responding in an appropriate manner. While we do not know exactly what the calls mean, it has been suggested that they are a method of keeping in touch with members of the herd and strengthening group solidarity. It may be that we can design an acoustic device that mimics this behaviour by sending an audio signal and waiting for the elephant to respond. This concept is explored in *Chapter 5: Design and Craft.*

Long distance navigation is not a topic we can hope to address, given the size of the typical enclosures. However, the responsibilities of being a leader would provide some interesting challenges for an elephant – and offering a challenge is something we might be able to do, for example, in the context of a game. A playful interactive device would definitely involve the elephant in controlling a system, which means making choices and taking the decision whether or not to perform an action. Allomothering, on the other hand, is another behaviour that is beyond the scope of our research, since this clearly depends upon the herd and the possibility of births.

In conclusion, fieldwork has revealed that elephants have different personalities and different interests – one game or toy is unlikely to be popular with all animals. Any device should be designed to work indoors, inside one of the sheds, and must be secured very well on the other side of a strong wall so it cannot be damaged, or cause damage to the elephant. A device that provides acoustic and haptic feedback may be interesting; keepers are confident that the full body kinaesthetic feedback provided by a shower would be worth testing. The interface to any system should require the use of the trunk, but probably only the tip. Care must be taken with animals in shared enclosures to ensure that using the device is enriching for everyone and does not become a focal point for aggressive behaviour.

Design and Craft

In this chapter, we document the process of designing and crafting devices for elephants, explaining in detail our rationale for design choices and describing what happened when we tested the devices with their intended users. The work presented here draws on theory from an extensive literature review of elephant lifestyle as well as insights gained during ethnographic fieldwork and interviews with stakeholders and other elephant experts – as discussed in *Chapter 4: Understanding elephants*. Having researched wild elephant characteristics and investigated the experiences of captive animals, we attempted to define elephant requirements and begin concept development (see Figure 2: Overview of Methodologies in *Chapter 3: Methodology*). We brainstormed ideas, discussed them with keepers and animal experts and took careful note of any feedback or insights. Undertaking this early ideation supported the requirements analysis by bringing attention to the context for the design.



		INSIGHTS				
DEVICE	Date	Testing - tech - sensors	Output	Elephants - materials - dimensions	Location	People
WHERE DID WE START?		Hidden sensor that captures proximity or touch - CAPACITANCE SENSORS		Experts recommended large pipes or buckets for trunks to explore - DRAIN PIPE	Safety first - trunk tip access - try BROWSE HOLE	Build prototype at home, take tools to Skanda Vale to WORK WITH KEEPERS on location
PIPE	Mar-15	**Early warning of capacitance sensing interference with 3 buttons.** Use a different sensor technology – push-to-make button seems simple. What can go wrong?	Acoustic	**Valli's trunk is bigger than you imagine.** Do some measurements and ensure that subsequent button is large enough – choice of shallow plastic bucket.	**Avoid using a browse hole.** Strong association with food means she will always trigger button BECAUSE she's looking for snacks. Need to find another suitable location – trunk-tip access, easy to fix.	**Peter's construction skills.** Aim to come with a ready-to-use prototype so as not to impact too much on keeper time.
		Calibration impossible in lab for trunk in field. Capacitance of trunk is very different from human hand? Would always need to be re-calibrated.		**Potential interface design.** Valli could definitely use a pipe as a "button".	**Requires a lot of trust** - Valli can't see what's beyond the browse hole, so she has to rely on her other senses and only receives feedback when she has already triggered the device. If she didn't enjoy the output, this might be alarming. To consider.	**Don't let Stefan use bananas!** Clarify appropriate methodologies for testing prototypes with animals – emphasise that we want to avoid food motivators and allow Valli to learn how to use button herself.
					Can she even hear beeps on other side of wall? She probably can, but may not associate them with her actions. Provide more obvious feedback?	**Keeper enthusiasm for shower control.** Stefan is very keen to test shower controls, so we'll move forward with a button that triggers water – a more obvious output than beeps and also supporting collaboration and teamwork.
CONCLUDE		PUSH-TO-MAKE		PLASTIC BUCKET	NOT BROWSE HOLE	KEEPER TIME / FOOD / SHOWER

Figure 27: Example Table of Insights, taken from workbook.

This work led to some refinement of ideas such that we were able to start crafting prototypes and test those artifacts with elephants and their keepers. We call this Research through Design *and Craft* since the crafting process is such a fundamental aspect of the work, because of our hands-on careful creation of objects, and because of the growing emphasis on the *form* of the design, in conjunction with its *functionality*. Additionally, we began to experiment with both traditional and high-tech techniques (e.g. knitting and embedded haptics) for creating interfaces with tactile interest. *Making* and *building* generally refer to the construction of an object; *manufacturing* suggests an industrial process; *crafting* emphasises the skill and artistry required to apply traditional methods to the physical creation of something new. A person who crafts might be following a pattern or a blueprint but could also be developing a new design.

The process involved lends itself to presentation in annotated workbooks, each focusing on a different feature of the design and development, and we include three workbooks as part of this chapter. The workbooks capture the key design decisions taken and serve as shorthand for the extensive craft and technical development that took place, condensing many weeks into a few pages. The workbooks presented here have also been influenced by the work of Sousanis (2015) and Dykes et al. (2016) in that we have been able to situate images and text in a way that facilitates understanding. For example, in the Input and Output workbooks, we present source material relating to elephant behaviour alongside the ensuing ideation; here we are able to present concept development as a visual narrative. An additional layer of meaning has been added by embedding links to audio and video material that exemplifies the work. Each design iteration is accompanied by a Table of Insights (see Figure 27), representing some of the knowledge gained as a result of testing prototypes. Our insights were both personal and derived from observation and interpretation of the elephants' behaviours contributed by the elephant keepers, who were also willing to supply critical appraisals of the designs. We used their feedback as qualitative evidence from experts to support our insights.

Research through Design emphasizes the gradual development and refinement of concepts, with each iteration informing the design choices of the next. Our work has been very much about process and the evolution of design, tracing how particular contextual knowledge has been re-invested into the crafting of a new object and how gradually, with repeated design iterations, some of that knowledge has become more generalised. Each version of a design serves as a test for insights derived from the previous attempt.

The documentation of this work in the workbooks reveals the insights gleaned and conclusions drawn through this process and demonstrates that omissions are as useful and illuminating as the selections made by designers when re-working their ideas.

This chapter comprises:

5.1 Enrichment Goals and Concept Development

Our concepts evolved over several months as we discovered more about our potential users and began to test designs in the field. Concepts that were informed by our investigations were initially formulated as labelled sketches, descriptions and miniature cardboard prototypes. When our ideas reached a usable stage (in terms of both suitability and feasibility), they were shared with keepers and animal behaviour experts.

Ultimately, we wanted the elephants to be motivated to play with any device we introduced, so - based on the understanding of the species we had developed - we needed to try and imagine what qualities a system might have in order to appeal to an elephant. The following topics influenced our concept work because they represent aspects of wild elephant lifestyle that may be missing in some captive elephants' experiences.

(i) Social experiences – e.g. antiphonal calling
(ii) Object and loco-motor play
(iii) Having control over aspects of the environment
(iv) Making meaningful choices
(v) Cognitive challenges and the need to adapt

There are several types of enrichment we could have offered: food, environmental, social, cognitive, sensory (Young, 2003). Most environmental enrichment encompasses more than one category, and sensory enrichment almost always includes more than one sense, as we discovered.

Food

We have been clear from the start that we wanted to explore alternatives to food rewards in our enrichment designs. Although elephants spend a large portion of their time budget foraging, which means that searching for and consuming food is a natural behaviour, we know that food enrichment is already well established in many zoos. Additionally, because food is used for rewarding animals that are being trained, we believed that a device that offered food would be used by an elephant (for the food reward) irrespective of whether the elephant enjoyed using it. We were keen to discover what other experiences would be sufficiently motivating for an elephant, such that she would choose to engage with the experience voluntarily regardless of extrinsic motivators such as food.

Environmental

Large scale installations or changes to enclosures were well beyond the scope of our work. We needed to find some interesting solutions that were portable, easy to install and maintain, that did not require heavy machinery and that used technology to facilitate outputs.

Social

Similarly, while we have always been interested in exploring possibilities for encouraging social behaviours, some aspects of elephant management were outside our control. Working with a single Asian female elephant at Skanda Vale (Valli) afforded the opportunity to design for one without needing to consider the hierarchies between members of a herd. On the other hand, while working at Noah's Ark, we were requested to manufacture two identical systems so as not to provoke competition between the two young African males.

Ideas for cooperative toys were considered, but the fact that the majority of our development work has been done with Valli has focused our research on the needs of a single elephant. We wanted to offer Valli an opportunity to develop some of the cognitive and sensory skills she would have needed if she was living naturally in a herd. As a result, we have tried to create systems that stimulate the kinds of behaviours shown by elephants in herds – specifically listening to others and discerning both the nature of a call and its provenance.

Cognitive

It can be argued that any novel device offered to an elephant will provide cognitive enrichment, at least at first while she is learning how to use it. Ideally, we hoped to invent a system that continued to offer cognitive stimulation. For example, the idea of a call and response game maps onto the behavior of antiphonal calling, when friendly elephants exchange rumbles within the herd.

'*Simon Says*' was a 1970s computerized toy developed by Hasbro (2020) that showed a sequence of lights to the player, who then had to tap in the same sequence in order to progress. The sequences gradually became longer, so the game involved memory and concentration. We considered adapting this idea using sounds, so the elephant either had to use a control to activate a sound (in response to one she had heard) or indeed make a suitable noise herself. However, the success of such a toy depended on whether Valli or any other elephant showed interest in engaging with an interactive acoustic instrument in the first instance. If she spent some time playing with one kind of acoustic toy, we hoped we might in the future be able to introduce a structured, game-like experience that would be more cognitively challenging.

Sensory

There are various kinds of sensory enrichment – olfactory, gustatory, visual, tactile, auditory. As we identified our goals to be associated with auditory provision, much of the development work explored this topic. However, during our investigations, we became increasingly aware of Valli's interest in the tactile qualities of our devices. In addition, we speculated on possible designs for olfactory enrichment (in this chapter, *WORKBOOK: Ideation and Production - Input/Output: Olfactory*), although none of these concepts have been developed into prototypes or tested with elephants.

In fact, every device we created had visual, olfactory, auditory and tangible properties, discussed as part of our analysis of the fieldwork in *Chapter 6: Reflections on Design and Craft.*

A useful way to share a novel concept with other people is to present it visually, as well as describing it, which is why most of the examples we show in the workbooks are in sketch format. In many cases, the ideas have been discussed with elephant experts, keepers or animal behaviourists. Their feedback has been invaluable, both for filtering out unsuitable ideas at an early stage and in refining concepts with potential so that they become more relevant.

As a case in point, one of the original ideas was to try and develop a playful experience that could be shared between an elephant and a human, to facilitate non-verbal inter-species communication (see water cannon sketch in *WORKBOOK: Output: Tangible – Early Concepts*). Phyllis Lee from the Elephant Welfare Group discouraged the idea of an inter-species game, commenting: '*From a welfare perspective, interaction with humans might be best avoided*.' During our EWG Skype discussion (Dec 2014), this issue was raised again. Lisa Yon said we should emphasise more naturalistic behaviour, although she thought it was better to be entertained and cognitively occupied than to have no interaction with humans. Oliver Burman pointed out that it was difficult to dissociate activities from human interventions. Ros Clubb advised that unpredictability should be a key feature of any such inter-species game - but, while visitors could potentially activate the system, it was important to ensure that it was not visitor focused. There should be no waiting on the part of the elephant, as this was known to be a trigger for stereotypical behaviour (confirmed during fieldwork, when Colchester elephants were observed weaving while they waited for the public elephant-feeding ritual to start – at the same time every day).

The next section deals with *Elephant Requirements* – having selected some early enrichment goals based on gaps in the behavioural experiences of captive elephants (provision of cognitive challenges and acoustic stimulation), we began to consider details of system design by reference to elephant modalities for interacting with the world.

5.2 Elephant Requirements

This section reports on the early requirements that were established for an elephant interface. This work was undertaken in parallel to the ethnographic study that was described in *Chapter 4: Understanding Elephants*, and prior to the development of prototypes.

There are two aspects to the challenge of defining elephant requirements – (i) practical issues dealing with HOW an elephant might be physically able to interact with any system; (ii) criteria for enrichment that underpin the design of a playful system for elephants.

Interacting with a computer system is a form of conversation, with the user providing input and the system outputting a response that mediates the subsequent action or reply of the user, thereby facilitating an engagement with the system. With this part of our research, we were addressing the question of design characteristics, and specifically investigating the design of interfaces (and experiences) for elephants.

The earliest computational systems (such as an abacus, a difference engine) were physical products requiring human tactile intervention. Computers have for years relied upon a keyboard and a mouse for user input – both devices that are designed for hands and fingers. Keyboards and mice are essentially collections of buttons. They can input both digital (pressed or not) information and analogue (how long did you press) information, depending on the programming of the underlying system. Modern variations such as tablets and mobile devices still emphasise touch as a mode of interaction, although VUIs (voice-user-interfaces) are now commonplace and console input devices such as Wiimote and Kinect offer gesture-based alternatives.

However, when considering interface design elements for different species, it is important to consider a species' normal modes of interaction. Humans used vocal communication and gestures to interact with each other long before the invention of buttons that controlled machines, but we have always used our hands to manipulate our tools.

For many years, human interface design has focused on *visual* representations. Buttons used to control elements of the system are typically viewed on a rectangular screen. In some cases, a well-designed interface becomes 'invisible' (Norman & Draper, 1986; Reichenstein, 2012; Schell, 2019) in that it disappears from user perception because it is so intuitive that the user can easily just focus on the task at hand (the interface enables the underlying system). Taking the point of view that 'invisibility' is a desirable quality for an interface suggests that development should be driven by the tasks and goals that users need to accomplish. However, it is also possible (and desirable) that the process of interacting is *a pleasure in itself*. It is therefore important for developers to work closely with users in order to understand their perspective.

Investigating the user experience is a holistic approach that takes into account the context, the goals of the users and their individual knowledge and skills, as well as the various forms of feedback that the system may offer.

Based on what we know about elephant communication as discussed in *Chapter 4: Understanding Elephants*, we created two tables that synthesized information relating to suitable inputs and outputs of a device aimed at elephants. *Table 3: Inputs* provides an overview of some of the potential input elements that could be used for an interface design, giving pros and cons for each. *Table 4: Outputs* shows a summary of the kinds of outputs that might be offered by a system designed for elephants.

Table 3: Inputs

Type of sense	**Body-parts used to produce**	**INPUT control mechanism**	**Examples**	**Pros**	**Cons – technical**	**Cons – for elephant**
Acoustic	Trunk, feet	Noise production	Microphone captures soliciting play with trumpet, stomping, antiphonal calling	Might encourage production of range of sounds	Challenging for system to decipher and respond to differences in waveforms	
Seismic	Trunk, feet	Low frequency noise production, vibration	Piezo element senses rumbles, stomping	Very ‘elephant’; technology can help decipher	Outside human auditory range	
Tactile – Cutaneous (texture, vibration, force)	Mainly trunk	Motion – e.g. touch, turn, pick up, grasp, pull, push, squirt, suck, reach	Kinect, capacitance sensor, lever, pulley, handle, button etc.	Lends itself to cooperative tasks; physical objects have multiple affordances	Manufacturing limitations – must be robust and safe; production costs; availability of materials.	Small objects potentially dangerous
Tactile – Cutaneous (temperature)	Whole body	Radiation of heat	Thermal sensor	Could sense proximity		Elephant not in control of heat emitted; no fine-tuning; influenced by other environmental factors
Tactile – Kinaesthetic	Whole body	Stand, flap ears, walk into zone, push object	Capacitance sensor, floor button, boomer ball	Would exercise a variety of muscles	Large objects difficult/ expensive to manufacture; must be robust	
Visual	Eyes	Gaze in a particular direction	Eye-tracking software	Could determine what generates visual interest		Obtrusive and might impair natural behaviour
Olfactory and taste	Trunk, vomeronasal organ, glands in feet, ears, eyes, reproductive organs, anus	Exude pheromones via glands		Out of scope but would be awesome to build our knowledge in this area		Chemical production related to health so not deliberate choice, therefore not appropriate for controlling input

Table 4: Outputs

Type of sense	OUTPUT sensed by elephant	Examples	Pros	Cons - technical	Cons – for elephant
Acoustic	Range of sounds	Could control volume, pitch, timbre, rhythm, channel etc.	Relatively untested – anecdotal interest in percussive sounds		Pervasive – affects all but solicited by one.
Seismic	Low frequency sounds or vibrations	Rumbles – didgeridoo and organ pipe samples	Can be generated acoustically but activated digitally	Digital version requires big speakers	
Tactile – Cutaneous (texture, vibration, force)	Haptic or motion feedback	Pulse or vibration in lever; object opens, rolls, breaks apart		Difficult to make both sensitive but strong enough	
Tactile – Cutaneous (temperature)	Heating and cooling system	Wall heats up or cools down; ventilation system – fans and windows, water temperature	Keepers keen on allowing elephants to control environment	Depends on existing enclosure – some features may already exist, others would be expensive to install	
Tactile – Kinaesthetic	Change that affects whole body	Pulse or vibration in floor or wall; spray of sand of waterjet, fountain; fans – feeling air movement		Size of elephant may restrict the design of a feature that would give a kinaesthetic experience	
Visual	High contrast graphics, different quantities of object, change position	Object opens, rolls, breaks apart; visual display via screen or lights; solar-powered umbrella; sliding bar	It is likely that a physical object will transform by moving in any case		Visual acuity believed to be poor
Olfactory and taste	Release different smells – chemicals, tiny amounts of food	Sniffing to detect which container has previously held food; using scents to discriminate between objects; puzzle feeders		Human olfactory sense is poor, therefore hard to create a subtle experience	Aiming to avoid food or signal for food as motivator

Summary

Elephant communication (See *Chapter 4: Understanding Elephants*) suggests that modalities for interfacing with a toy/game should focus on tactile, acoustic or chemical properties, rather than relying solely on a visual display. '*They live in a world that is largely acoustic and olfactory (2–5) rather than visual…*' (Plotnik and De Waal, 2014).

For the purposes of our elephant experience design, we concluded that using *scent* markers to identify different controls could be counter-productive, particularly as we were aiming for enrichment that was not related to food. We did not wish to set up false expectations. On the other hand, using *sound* cues for buttons that produce acoustic enrichment seemed logical. Similarly, we thought *haptic* feedback seemed to be more suited to controls that activated a kinaesthetic experience.

Using a remote sensor such as Kinect to sense trunk movement could have been one way for an elephant to provide input to a system. Oliver Burnam (EWG) described simple beam-breaker sensors used with rats, suggesting these as an easy way to enable the rats to trigger events by poking their noses through a hole. This would have also been consistent with Ros Clubb's (EWG) recommendation for differentiated holes that trunks could explore as a possible interface. However, the observations of elephants led us to conclude that they would be more likely to understand a *tangible, physical interaction* with a system, as this is how they interact with the real world. It would still be possible to use a hidden sensor to capture interaction data, as long as the trunk experience was physical and tactile, possibly with haptic feedback.

Discussions with keepers suggested that the first step should be to establish a workable interface mechanism for the elephants, allowing them to control something in their environment that was usually controlled by keepers. The system could permit the user to make a binary choice (yes/no) regarding whether to play a sound or which sound to play, using a simple on/off type of button control. When the mechanics of such a device had been learned, it might then be possible to offer different kinds of stimuli, using similar controls so that they were familiar, and thereby assess how effective other systems (acoustic toys, for example) could be at providing different kinds of enrichment.

Earlier discussions with animal behaviourists and keepers during 2014 (EWG meeting; Claire Bennett, Head Elephant Keeper at Colchester Zoo; Brother Stefan, keeper of Valli the temple elephant at Skanda Vale Ashram) suggested that elephants might be capable of using such a system, although without testing a prototype, we could not gauge their level of interest.

Thus, the first serious development work involved inventing and manufacturing some different kinds of digitally enabled systems and testing them with some friendly elephants in order to understand what might be feasible (for an elephant) with regard to using controls. How might an elephant be physically and cognitively able to interact with a system? What qualities would make such an interface easily usable for an elephant? The physical aspect related to the design of an object that an elephant could control using its evolved way of interacting with the world. The cognitive aspect related to the design of a system that an elephant could understand. As Krippendorf (1989) notes, meaning is a cognitively constructed relationship connecting features of objects and features of their context into a coherent unity.

Sensible UX design for an animal would make use of their existing knowledge of the world and simplify the controls so that these were natural to activate. This is an important aspect of interface design known as *affordance* – the idea that an object offers its user an indication of how to interact with it and sometimes also shows its functionality through properties that the user can perceive, such as its form (Norman, 2013). Thus, we might assume that a branch-like structure would suggest to an elephant that it could be tugged (and moreover that it would offer resistance). In fact, although our initial concept designs included such controls (bungee ropes as pulleys), at first there were insurmountable difficulties associated with mounting these safely from the roof of the elephant shed in which we tried to install them. Years later, when we did manage to test ropes, we realized how difficult it would be to capture details of elephant interactions using embedded sensors. For example, in order to understand how the elephant was manipulating the interface so that we could map this to a responsive output, we would need to know with what force she pulled, or twisted, or in which direction the rope was swung.

This highlights one of our major challenges and, therefore, one of our goals: the construction of interfaces that were sufficiently *robust t*o be safe, using materials that could be repurposed or bought relatively cheaply and which were both *easy to install* and *easy to work with* using our available equipment.

The workbook that follows (*Ideation and Production*) provides an overview of research and development relating to design concepts and the crafting process.

Ideation and Production

This workbook showcases a selection of **concept pieces** produced during the project as well as providing an introduction to **design considerations** that arose when we started crafting prototypes.

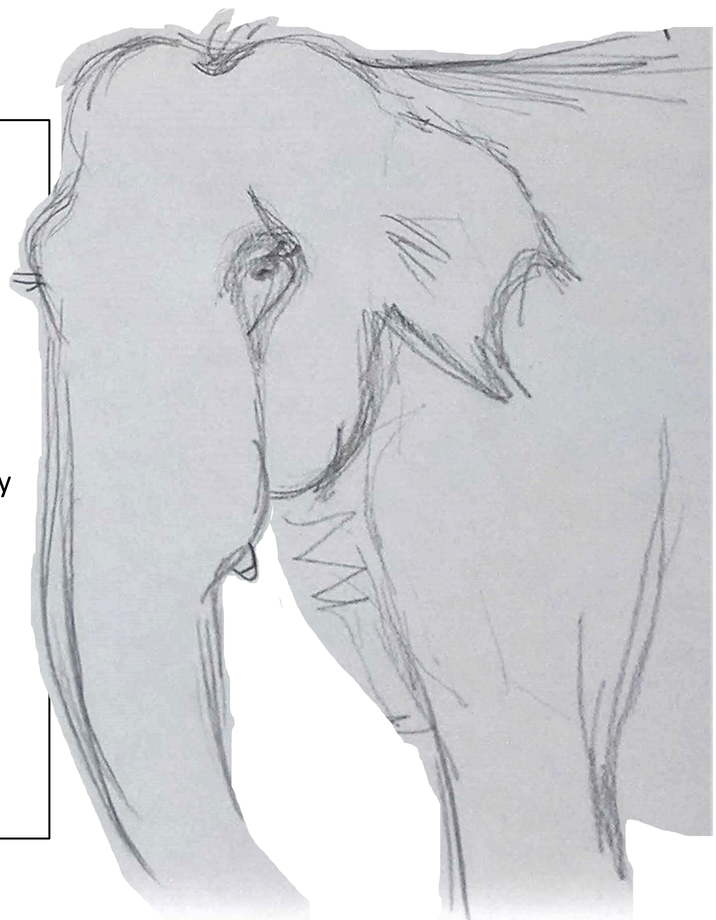
Early ideas have been sketched and annotated following discussion with animal experts. This is followed by an overview of insights gained, which informed the next stage of idea development. We have summarised these early insights in the diagram: ***Framework for Design and Craft.***

The next stage of development involved working with colleagues to identify suitable elephants and to build, install and test prototypes. The topics we investigated are expressed in the diagram: ***Application of Design and Craft***.

We then present some more concept work that helped clarify our ideas despite being outside the scope of this project.

The next workbooks in the sequence – Input and Output – all follow a similar layout whereby we present concepts, showcase their development and the working prototypes, then summarise each intervention with a short overview of insights.

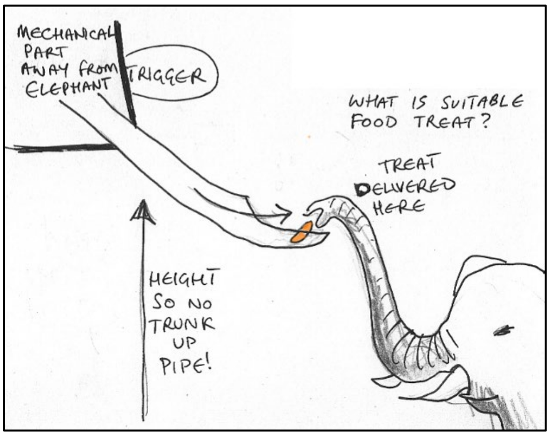
CONTENTS



Early Ideas

(2013-14)

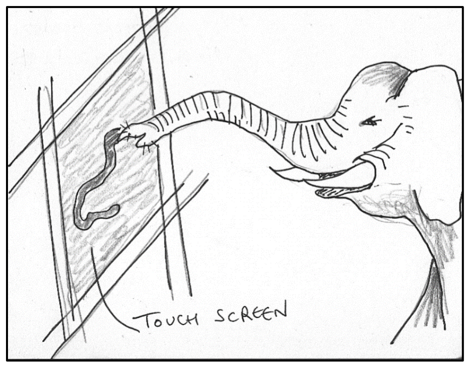
CONCEPT WORK

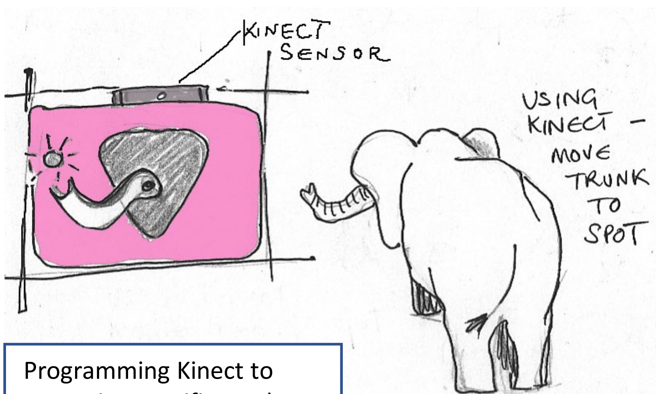


Keepers always keen on food provision, but I'm not…

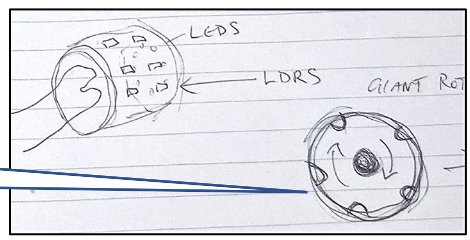
In fact, Dublin Zoo have implemented a device similar to this, except that the food drop is triggered remotely by a keeper who has received a mobile alert that the elephant is trying to obtain snacks (so there's a sensor involved).

How could we make and safely install an elephant-proof touchscreen? What might it cost?



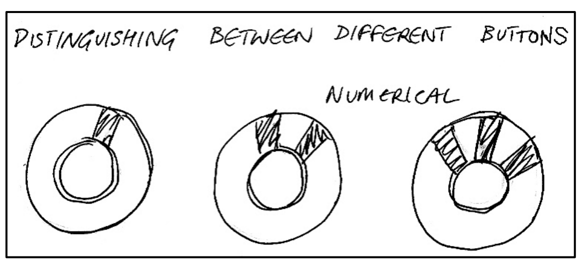


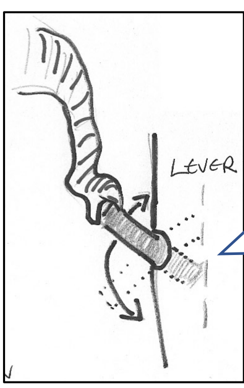
Programming Kinect to recognize specific trunk movement is an interesting challenge but beyond scope of this project.



Giant balls out of our scope

There are many ways to differentiate between similar buttons, including hierarchy, scale, colour, position… Could an elephant understand significance of different numbers of stripes?





How to mount lever that is sufficiently robust? What materials required? Amount of leverage? Too tricky

Early Ideas

CONCEPT WORK

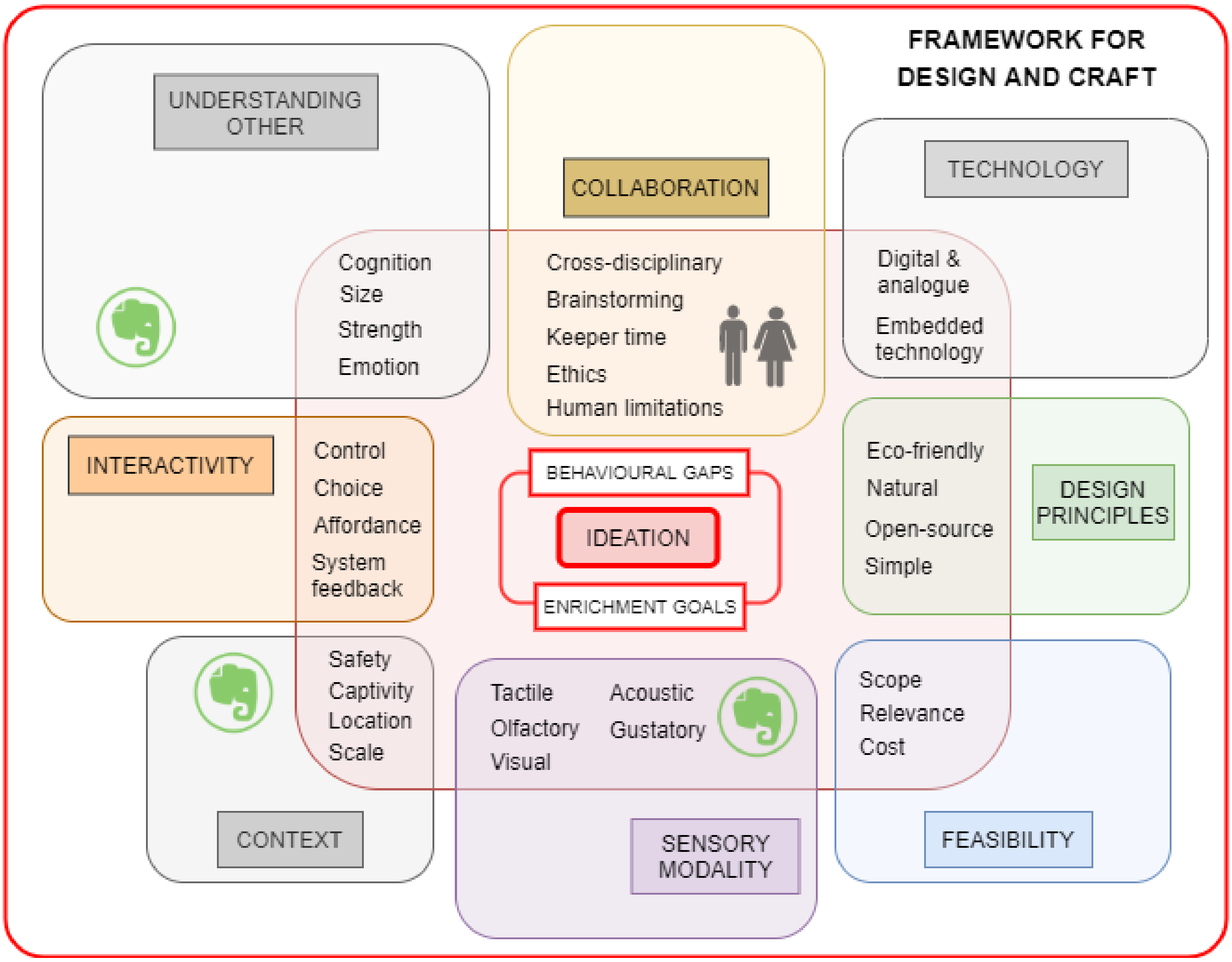
		INSIGHTS				
CONCEPT	**Date**	**Feasibility**	**Functionality**	**Elephants**	**People**	**General**
EARLY WORK	2013 - 2014	**Manufacturing.** With limited workshop facilities, some large pieces of equipment are beyond scope of the project.	**Technical considerations.** Some ideas require a large amount of background work to enable – although interesting, this might not be part of our brief. Keep strong focus.	**Elephant strength.** Devices must be sufficiently robust, without small or large removeable parts or any accessible electronics. This relates to safety.	**Time.** There is limited time for developers, and also we don't want to impact on keepers too much because they have final say on whether devices can be deployed in enclosure.	**Design ethics.** Are we working with any general principles of good practice in design?
		Simplicity. Some mechanisms would be very complicated to construct from scratch - try to keep it simple.		**Scale.** Elephants pose their own challenges due to their size and the dimensions of the enclosure.		**Materials.** Have to be sure nothing poisonous if ingested – a bit like prototyping for children - so best to come up with designs that can use natural materials if possible.
		Cost. Some of the concepts cost too much – sadly no budget or grant available at present!		**UX Design principles.** What do the elephants think? Need to make something and test in field.	**Suitability.** What do the experts think? Some of these ideas might not be appropriate for captive elephant. Ethical considerations with regard to animals.	**Questions.** Every concept seems to raise more questions than it answers!
						Safety. Everything for animals has to be checked for safety.
CONCLUDE		SIMPLE / COST / CONSTRUCTION / SCOPE	RELEVANCE	SCALE / STRENGTH / CONTEXT / CRAFT / TEST	COLLABORATION / FACILITATION / EXPERT ADVICE / ETHICS / TIME	ECO-FRIENDLY / OPEN-SOURCE / NATURAL / SAFE

Our early concept work was done in parallel to a study of elephant requirements (for interface and system design), based on what we know about their physical, cognitive and sensory characteristics. This complementary work is described in detail in this chapter ***Section 3: Elephant Requirements***

Elephant requirements

(2014)

		INSIGHTS				
CONCEPT	**Date**	**Feasibility**	**Functionality**	**Elephants**	**People**	**General**
ELEPHANT REQUIREMENTS	2014	**Games.** Can we design an abstract experience that practises real behavioural skills? We need clear enrichment goals.	**Interaction design.** How to have a conversation with a device - inputs and outputs that flow naturally.	**Sensory modalities.** Tactile and acoustic senses seem to be the most appropriate modalities to use for designing interface elements and device outputs.	**Teamwork.** Important to obtain advice from the experts.	
				Testing. Need to test rough prototypes in the field and gain some insight into what might work...	**Enrichment goals.** To keep our focus and to keep the keepers on board - we're relying on them to grant ethical approval.	
CONCLUDE		ENRICHMENT GOALS	UX DESIGN	MODALITY / CRAFT / TEST	COLLABORATION / ENRICHMENT GOALS	



The insights gained from ideation and investigation of elephant requirements are summarized here, showing the aspects we considered during this stage of the project. We have collected them into categories: Context, Feasibility and Functionality, Design Principles, Collaboration, Sensory Modality and Interactivity, and Understanding Other (an elephant).

As we embarked on our Craft stage and the ideas were taken into reality, physical manifestations and practical considerations filled out some of the details – these are exemplified in the following pages. Importantly, Interactivity and Understanding Other were still big questions at this stage… Iteration of prototypes and testing them with elephants gradually increased our knowledge about what would work – that part of our research is developed in the Input and Output workbooks.

DISSEMINATION / PUBLICATIONS ARISING

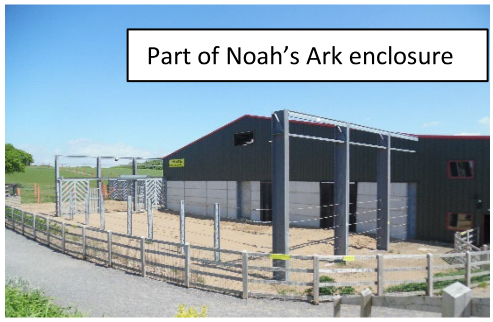
2014 French F, Mancini C, Smith N, Sharp H. Designing Smart Toys for the Cognitive Enrichment of Elephants. Presented at *AISB 2014* (Artificial Intelligence for the Simulation of Behaviour, Symposium on Intelligent Systems for Animals). http://doc.gold.ac.uk/aisb50/AISB50-S14/AISB50-S14-French-extabst.pdf

Context

LOCATION

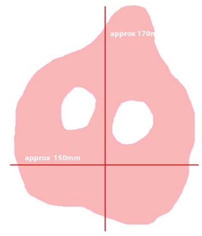
Space and volume – the importance of doing a **survey** of the captive environment.
Need to understand existing limitations; know where and how to fix novel systems.

Skanda Vale daily stroll

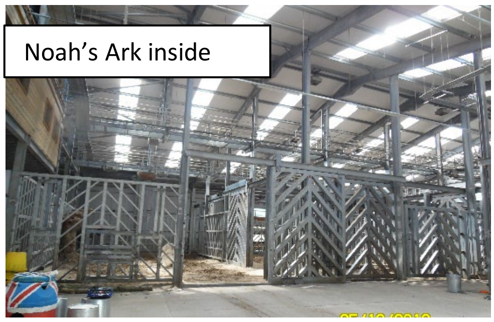


Part of Noah's Ark enclosure

SCALE
Trunks are BIG!

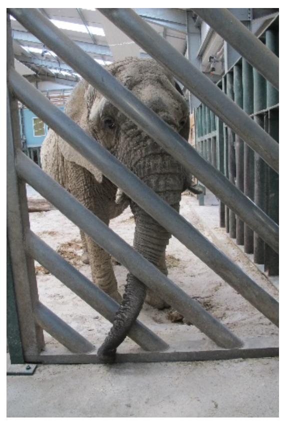


Skanda Vale inside

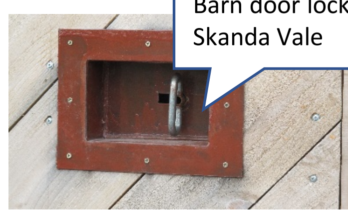


Noah's Ark inside

Tusk dents in steel bar at 2m height, Blair Drummond



SAFETY FIRST
Critical for enrichment to be robust



Barn door lock, Skanda Vale

Dublin Zoo

Colchester Zoo

Atlanta Zoo

Twycross Zoo

CAPTIVITY

Feasibility and Functionality

SCOPE

COST

RELEVANCE

Keeping the project viable – within scope

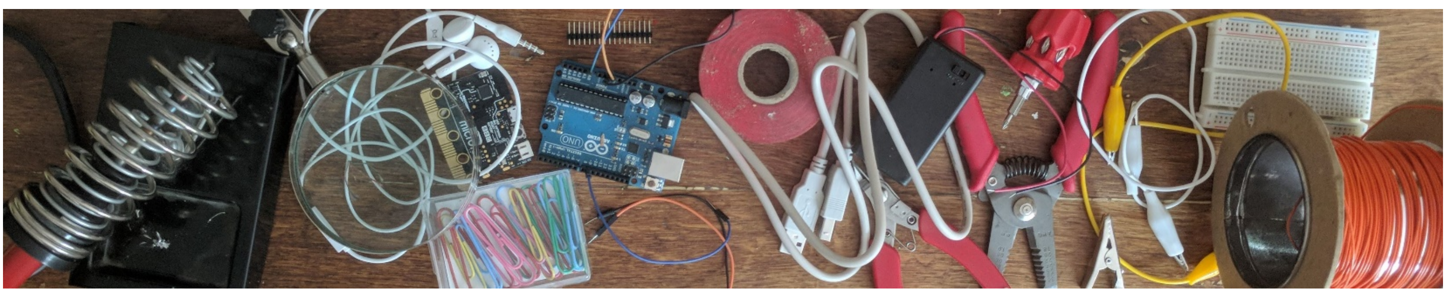
Meeting research needs – are we answering the right questions?

CONSTRUCTION

Tools – drill, saws, jigsaw, router, hammer, clamp, metal ruler, pliers, wrench, scissors, screwdrivers, penknife etc

Fixings – nuts and bolts, screws, glues, tape, hot glue gun, plasticine, rope, cable ties, wire, sandpaper

Sawdust and electronics don't mix well…

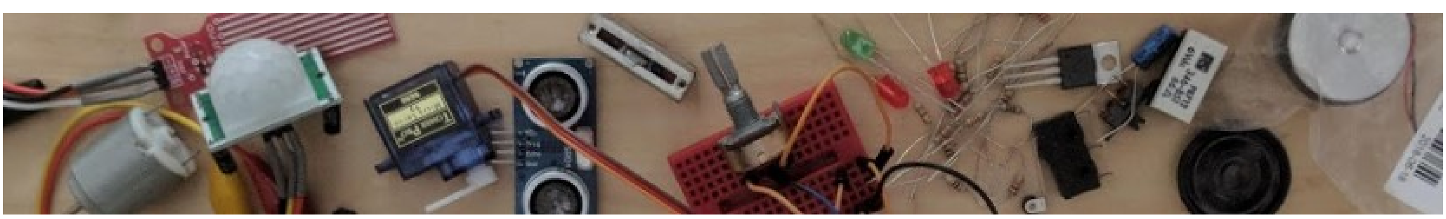


EMBEDDED TECHNOLOGY

Tools – meter, wire cutters, microcontrollers (Arduino, Micro:bit), wires, crocodile clips, breadboard, magnifying glass, soldering wire, electrical tape, headphones…

Components – e.g. resistor, mosfet, diodes, relay switches, capacitor, capacitance sensor, LDR, potentiometer, accelerometer, PIR, infra-sonic sensor, flex sensor, rotary encoder, push-button, motor, servo, light, speakers, solenoid valve, EMR and LRA vibrators, bone-conductor etc. For digital and analogue inputs and outputs.

Software – Fritzing, Arduino, Processing, MicroPython



Design Principles

Key values contributing to development work.

ECO-FRIENDLY

- **RECYCLE** found objects
  – drain pipe, plastic bucket, rope
- **REDUCE** waste – off-cuts and spare parts
- **REUSE** – repurpose existing mechanisms, e.g. drawer slider

NATURAL

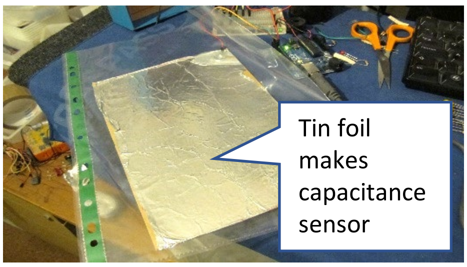
- Wood, hessian

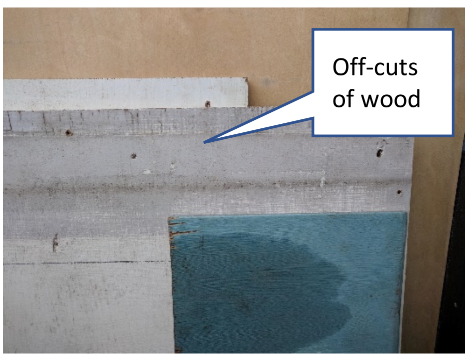
SIMPLE

- **KISS** (keep it simple, stupid)
- Make things achievable for non-experts
- Less to go wrong, easy to fix

OPEN-SOURCE

- Share with community – e.g. Instructables
- Dissemination – freedom, collaboration, education
- Software and programming – Arduino, VLC, Processing, Fritzing, Audacity, MicroPython
- Remember to document the process – camera, notebook and pen



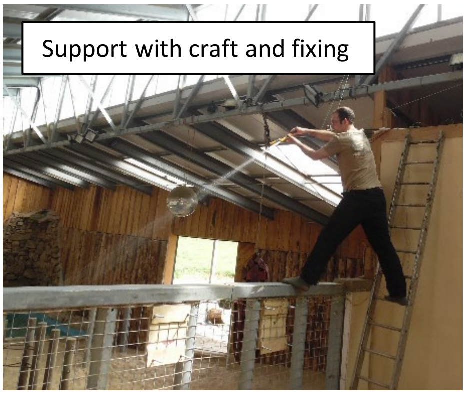


Existing browse hole has trunk-tip access – transform into safe space for tech test.

Unused sections of drainpipe found in back garden and in a field at Skanda Vale

Sliders salvaged from old drawers

Collaboration


Support with craft and fixing

KEEPER TIME


Talking to keepers at Twycross

BIAZA
BRITISH & IRISH ASSOCIATION OF ZOOS & AQUARIUMS

Advice from animal experts – BIAZA's Elephant Welfare Group

ETHICS

Permission and support from care-takers and keepers – ethics forms

Screenshot from BIAZA website

CROSS-DISCIPLINARY

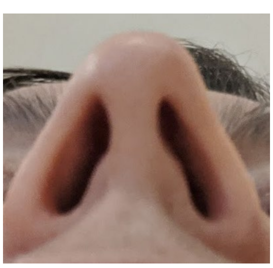
Working with other researchers who have a different agenda

BRAINSTORMING

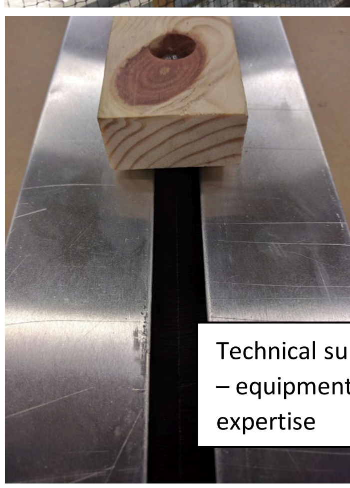
ZOO JAM

http://zoojam.org/

HUMAN LIMITATIONS




Talking to keepers at Noah's Ark




Technical support – equipment and expertise

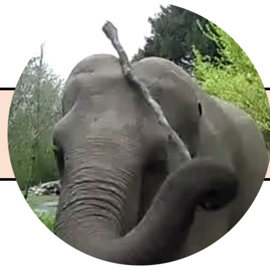
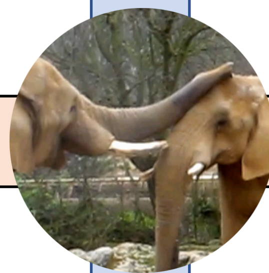
Sensory Modality and Interactivity

Senses overlap – should we try to separate them?

SIGNALS

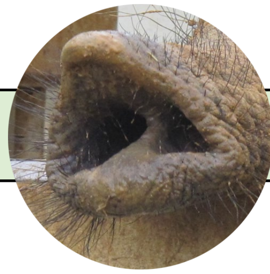
Trunks rule for interacting.

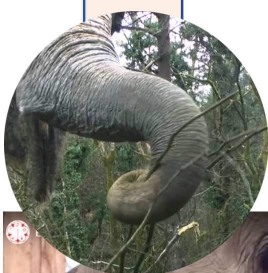
TACTILE


EVERYTHING IS

OLFACTORY





Sorry Valli – we're avoiding food rewards…

GUSTATORY

MINE!

I DON'T LIKE IT

BEING GOOD

ACOUSTIC

Turn the volume down!

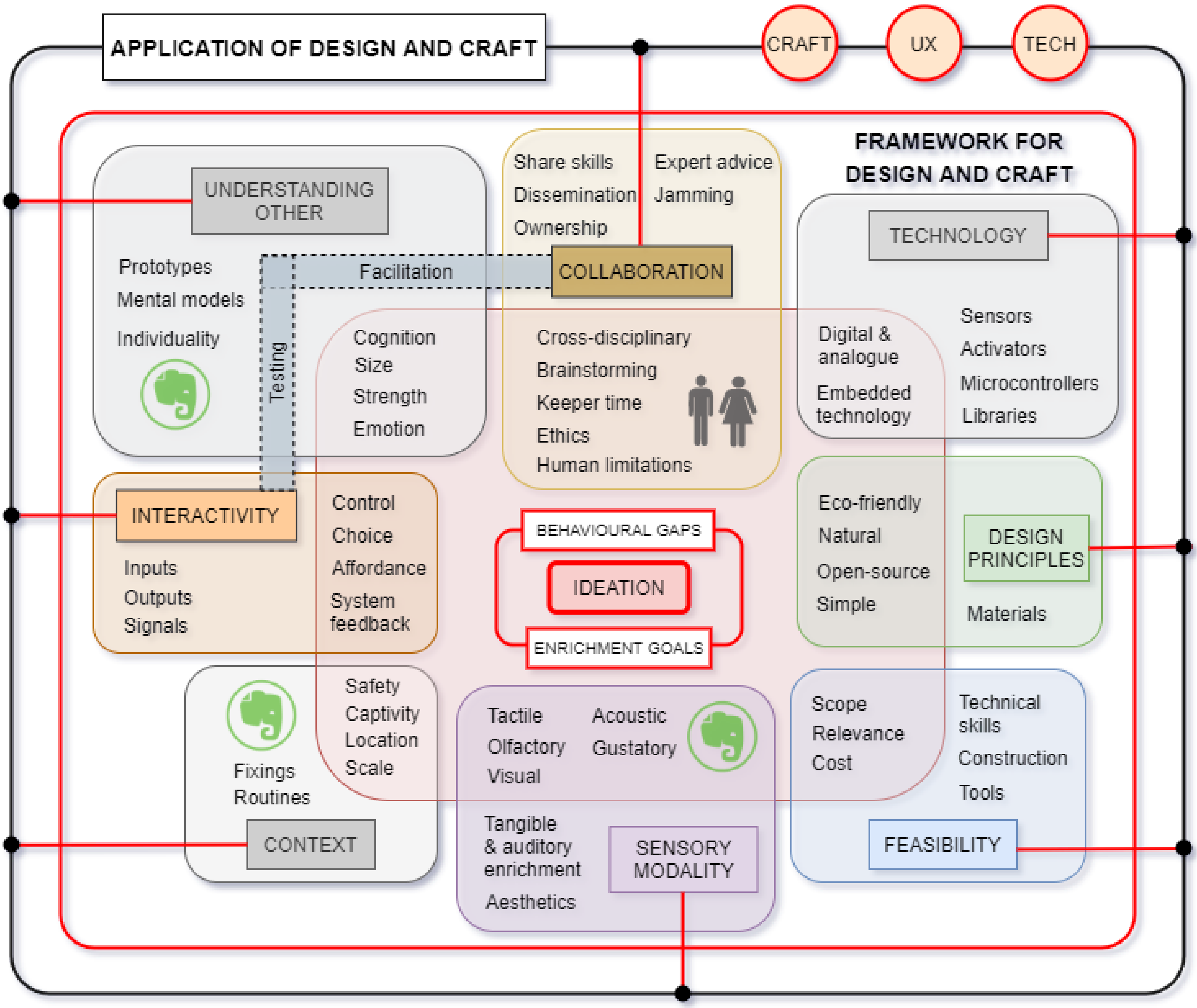
VISUAL

Understanding Other

Desert elephant calf, Namibia 2015

Herd at water hole, Etosha Namibia 2015

As we have seen, the development process included visiting animal care establishments, sharing and discussing ideas with keepers and other animal experts, designing and crafting prototypes, installing them and testing them with elephants. As this work progressed over several years, it became clear that there were further aspects to consider in each of our design categories. We have added these to the original framework below.



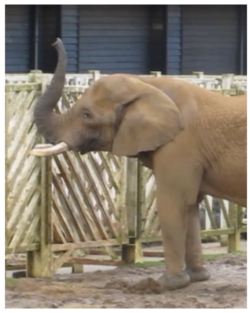
The following pages showcase some of our concept work related to olfactory and haptic experience design. Our prototyping work did not focus on these modalities, yet the creative process and subsequent analysis gave rise to many fundamental design principles that we took forward into our crafting phase.

Similarly, the SoundJam we describe here was the latest in a series of workshop events (ZooJams) that explored *ideas* for environmental enrichment associated with acoustics without progressing to a prototype development stage.

Input / Output: Olfactory

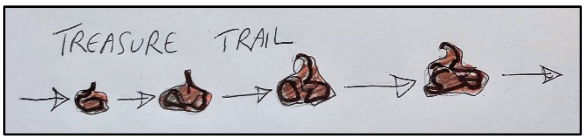
CONCEPT WORK

Valli knows there's a banana over there…

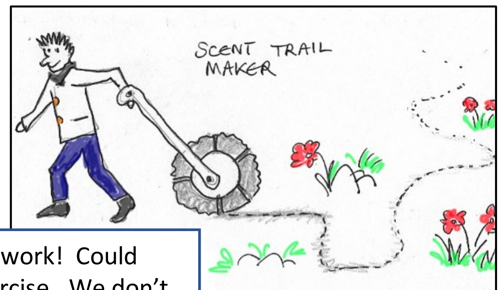


Up periscope!

Tembo smelling Zola's fresh poo message (it's behind him)

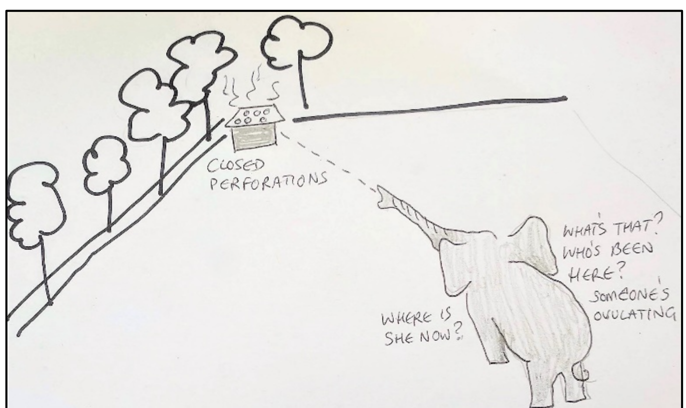


But who's at the end?

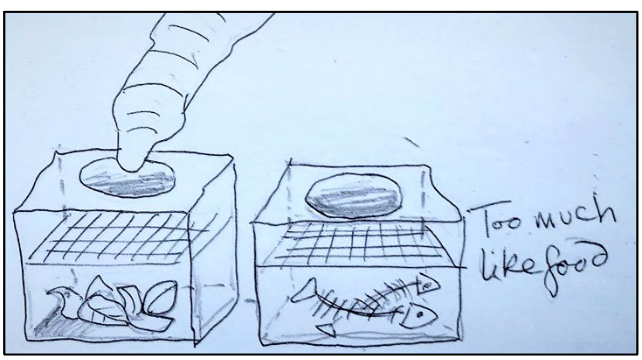


Might it be stressful to think someone has been on your territory?

Lots of keeper work! Could encourage exercise. We don't know enough about smells…



Messages need to be regular so that long-term knowledge is acquired.



What kinds of scented substances could we put into smell boxes? Artificial, human, other species, environmental…

Input / Output: Olfactory

CONCEPT WORK

		INSIGHTS				
CONCEPT	**Date**	**Feasibility**	**Functionality**	**Elephants**	**People**	**General**
OLFACTORY	2017	**Making a stink.** How would we generate or capture such a transient experience?		**Modality.** Using scent might be enriching, but as an output it doesn't offer much in the way of choice and control. More like watching a movie than playing a game. Could be used as a signal for something?	**Keeper interest.** Br Stefan has shown an interest and it's good to work with the keepers.	**Change of direction.** Would love to investigate olfactory enrichment, but probably not within scope of this project – future plans.
				Smells for Valli. A future direction for research, partly because it's an under-explored topic that has an aesthetic dimension, partly following up early concepts…	**Sensory deprivation.** Human sense of smell is so poor that we can't begin to understand the subtleties of what an elephant might be able to infer from the scent of something.	
CONCLUDE		**MATERIALS**		**AESTHETICS / MODALITY / CHOICE / CONTROL / SIGNAL**	**COLLABORATION / HUMAN LIMITATIONS**	**SCOPE**

After Brother Stefan ditched the idea of shower controls, he developed a new enthusiasm – olfactory enrichment. Part of the problem is that humans can't appreciate animals' sophisticated sense of smell. We discuss the potential for providing Valli with samples of poo from other elephants – needs to be checked with someone from EWG first.

Concept given go-ahead, then Lisa Yon links me back to Fiona Sachs at London Zoo in order to arrange a poo collection – ethics forms required first. Currently outside scope – to be explored in future.

As we explain in the Aesthetics section, it was clear that there was an olfactory experience associated with every device we made – it was just that we were unable to *design* for this experience – it was a byproduct with unknown potential for pleasure / interest.

Input / Output: Haptic

CONCEPT WORK

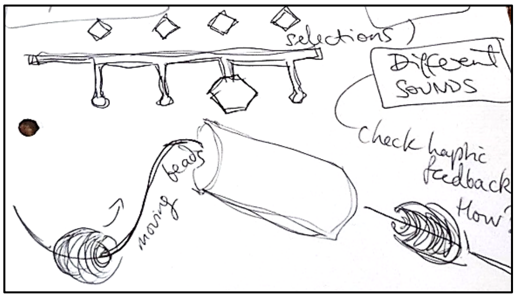
HAPTIC PANEL

2015 - 2019

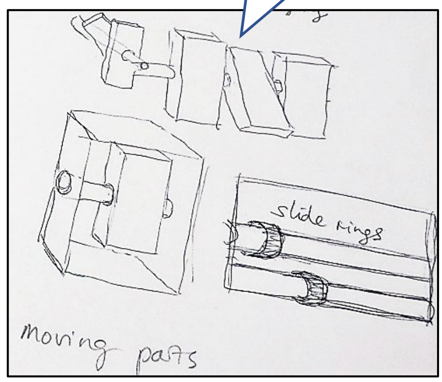
As the workbook on **Inputs** describes, we discovered that there might be potential for developing some haptic interfaces that could be interesting for an elephant. Intuitively, this seemed to be an excellent direction to follow, but the logistics of manufacturing and mounting a haptic panel in an elephant enclosure were insurmountable – too costly and lack of production facilities.

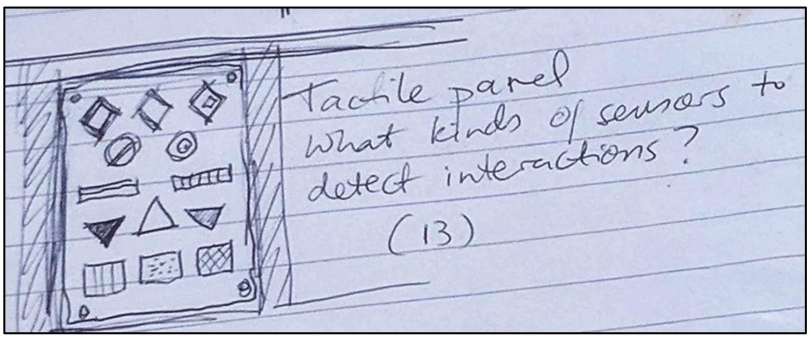
Some of the ideas shown below were used in the creation of 3 identical buttons made from a variety of different materials (Inputs/ Tactile/ Capacitance 2018) but without vibrations or different temperatures or flexibility.

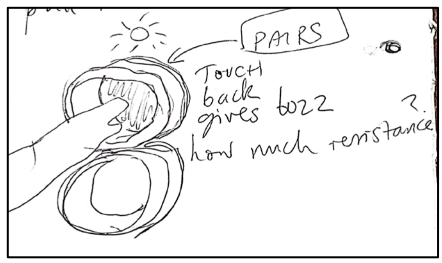
Can we make this sufficiently robust?

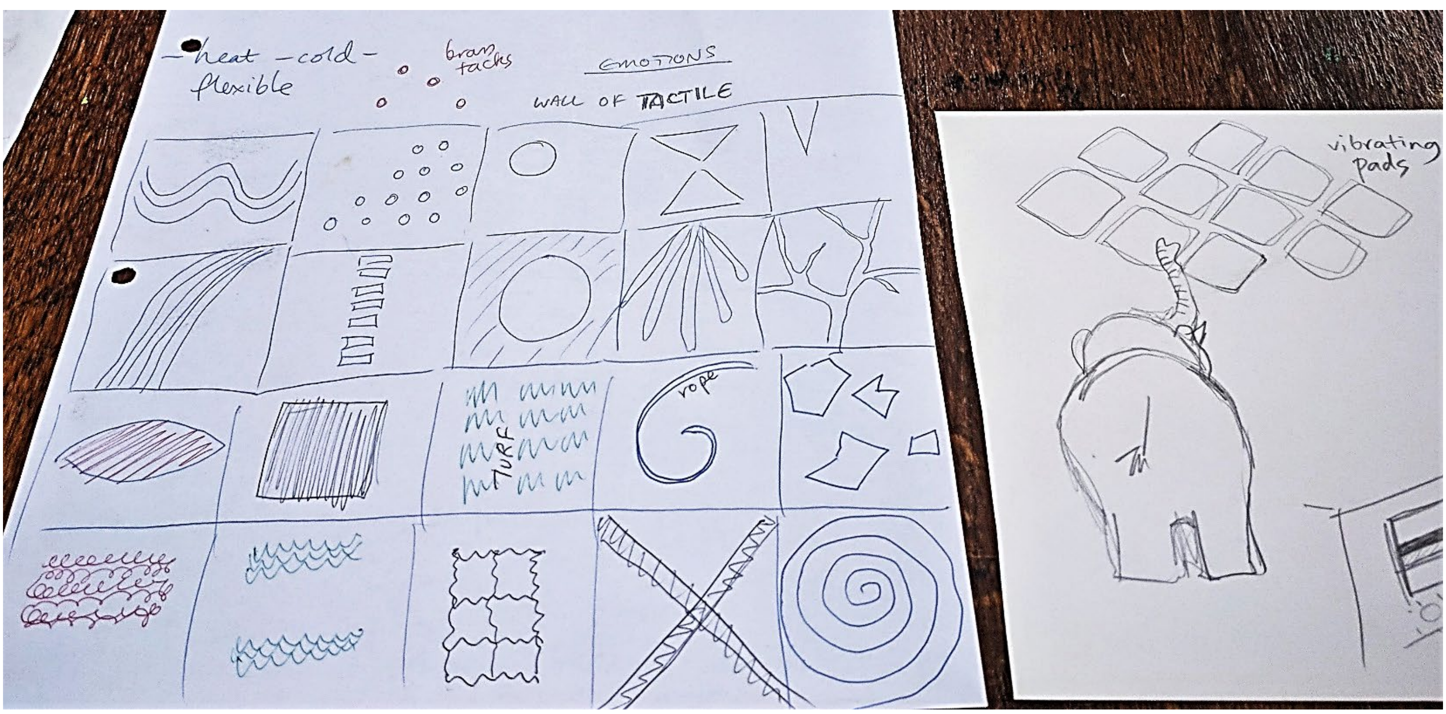


Modalities - can an elephant both hear and feel a vibrating motor?









CONCEPT WORK

		INSIGHTS				
CONCEPT	**Date**	**Feasibility**	**Functionality**	**Elephants**	**People**	**General**
HAPTICS	2015 - 2020	**Manufacturing and fixing.** We could probably make wall panels, but it's hard to know how we could fix them securely inside an elephant shed.	**Motors.** Vibrating motors easy to source; designing haptic feedback would be a new direction. Message to self - keep in focus!	**Merging modalities.** Holistic approach to sensory perception. Could feeling be the same as hearing for an elephant? Particularly at low frequency...		**Experimental.** Keep in mind that interactive devices for elephants have few precedents, which means there is not much previous work to build on.
				Good novelty value, potential for discovering more about elephants (and ACI), but we need to be careful about expressing generalisations derived from specific investigations.		**Haptics.** Expanding the modalities of UX design is very topical, with innovations in haptics and body-sensing and even digital smells (for humans). It's early days and although fascinating, beyond scope of this project.
CONCLUDE		**MANUFACTURE / FIXING**	**FOCUS**	**MODALITY / INDIVIDUALITY**		**INNOVATION**

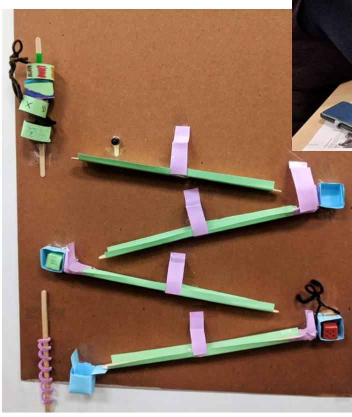
In the subsequent workbooks, INPUT and OUTPUT, we explore the tactile quality of our prototypes in some detail, so this work contributed to our analysis of tangible enrichment opportunities and associated aesthetic dimensions.

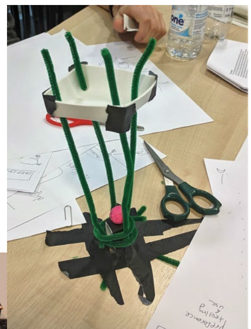
The final section presents the ZooJam workshops that were held at the annual ACI conferences 2016-18. In 2018, we focused on auditory enrichment and participants were given an opportunity to brainstorm concepts for elephants...

ZooJam

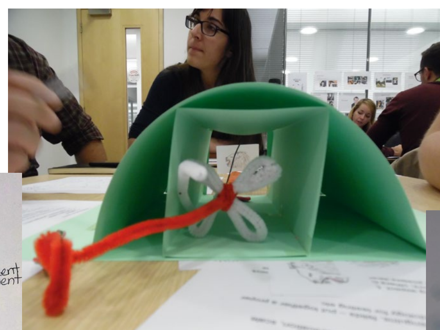
The ZooJam is a type of workshop whose aim is to extend the reach of UX design beyond human experience in order to become inclusive of other species and their interactions with technology.

Participants form teams and brainstorm ideas based on a specific enrichment theme.

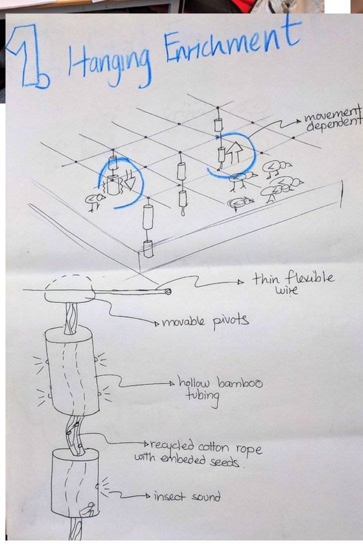


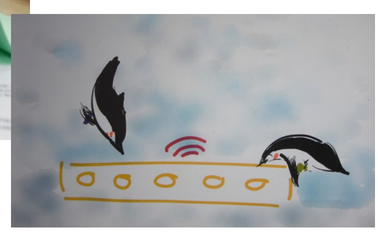


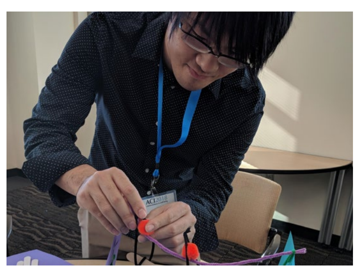
ZooJams attract a diverse mix of participants, including animal behaviour experts, zoo-keepers, interaction designers, programmers, engineers and others who are interested in designing for animal welfare.



The outputs are typically crafted prototype devices to share with the community.







Photos taken at ZooJam 2016, FarmJam 2017 and SoundJam 2018.

DISSEMINATION / PUBLICATIONS ARISING

2019 French F, Baskin S, Gupfinger R, Webber S, Zamansky A. ZooJamming: Designing Beyond Human Experience. Paper for ICGJ (International Conference on Game Jams) 2019. San Francisco, USA https://doi.org/10.1145/3316287.3316294

ZooJam: SoundJam

CONCEPT WORK

Organising committee: Fiona French (London Metropolitan University), Valerie J. Hare (SHAPE of Enrichment), Reinhard Gupfinger (Tangible Music Lab, University for Art and Design Linz), Paul Kendrick (acoustic engineer, Salford University)

Valerie Hare, Jacob Logas from Georgia Institute of Technology, Mike Szakaly from Indiana University discussing auditory enrichment for elephants.

SoundJam 2018 was a workshop held at the ACI Conference in Atlanta, Georgia, aimed at developing innovative concepts for auditory enrichment. Participants were tasked with devising novel acoustic systems for different animals, including elephants. Fiona French facilitated while Valerie Hare from SHAPE provided an animal enrichment specialist perspective and feedback on ideas.

Everyone contributed to the elephant brainstorming session, but we didn't develop any prototype concepts in the afternoon as we were a small group and could only focus on 3 different species.

http://zoojam.org/soundjam/

Interactive Audio for Elephants

Brief provided by Fiona French and Lisa Yon from The Elephant Welfare Group.

Elephants are naturally social, communicating within their herds, and as they live in a fission fusion society, when groups split off from each other, they often communicate over distance with others from their larger group.

INPUT

Must be: Sufficiently robust; relatively easy to install; easy for keeper to maintain – e.g. change batteries, dismantle, switch off; easy for elephant to control, and offer choice

OUTPUT

Please consider the nature of the acoustic feedback being offered – for example, is it biologically salient? Is this an important factor for the output to be enriching? What sounds might cause unwanted stress?

Auditory enrichment may be problematic in an environment with more than one animal – after all, we wouldn't expect everyone to enjoy the same music; some people prefer silence to any kind of noise; choice of music depends on mood. Therefore, any design must take into consideration the context and offer solutions for:

- Reducing the possibility of inciting competition for a resource.
- Avoiding domination by one member of a group.
- Eliminating (or reducing) unwanted auditory effect on others.
- Interfering with existing social structures.
- Capability of elephants to fling large objects at keepers and members of public!

CONCEPT WORK

CONCEPTS – NOISE INTERFERENCE

- Use **soundproofing**, dampening to stop too much noise echoing round shed. Shape of shed important – L-shape baffles sound, or pile of logs.
- **Cone of silence**! Umbrella with sound effects inside that covers elephant head.
- Cavity large/small enough for baby elephant head to go through! Sound inside only.

CONCEPTS – COOPERATION

- Individuals have preferences – **cooperative trigger** across a wall, so trigger on one side causes acoustic output on the other.
- **Elephant soundscape** – Skype across communities/enclosures, for distant communication. Good for staying in touch with distant relative or making introductions.
- Offer **multiple interfaces**, could harmonise, and less potential for fighting over resources.

CONCEPTS – TYPES OF SOUNDS

- Blowing **wind chimes** – **harmonica** would be interesting.
- Blow water/air – popcorn shooter exists – column air hits trigger, could be a **whistle**.
- Floor pressure piano plays **musical notes**.
- Rattle stuff, **percussion** - music?

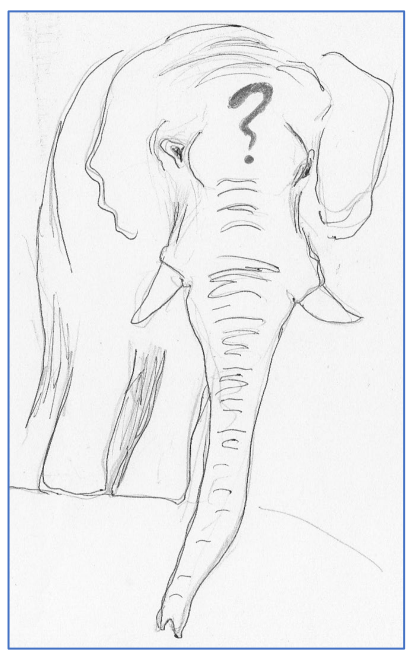
CONCEPTS – INTERFACE DESIGN

- **Cubby holes** for trunks to enter, slide closed when device off - timed play. Kinect inside to monitor trunk position (theraminish).
- Counterweighted **rope to pull as trigger** for elephant-based sounds, or other natural environmental sound such as frogs.
- Devices **outside enclosure** protrude through bars for safety; visual on/off signal.

QUESTIONS RAISED

- Do elephants have regional dialects? Can they understand each other?
- Can elephants decode remote vocalisations - what does that sound mean?
  And can they therefore provide an appropriate response?
- Should devices be under keeper control or automatic?
  Do keepers want extra responsibility or not?

Examples of elephant using wind chimes
(courtesy Valerie Hare)



CONCEPT WORK

		INSIGHTS				
CONCEPT	**Date**	**Feasibility**	**Functionality**	**Elephants**	**People**	**General**
SOUNDJAM	2018	**No problem.** Participants didn't seem to consider that manufacture might be an issue.	**Low-tech analogue is easier!** Lots of percussive ideas that would be relatively simple to install – reflective of technical knowledge of participants?	**Interesting questions.** Regional dialects in elephants? Do remote vocalisations hold any meaning?	**Interesting questions.** Keeper control or automatic? Issue of taking extra responsiblity / having ownership and control.	**It's a difficult challenge.** Reassuring to see that other people also found this a subject worthy of deep consideration with no simple answers.
					**Great to have animal enrichment expert as part of the mix.** Highlights the fact that there have been few opportunities to discuss ideas BEFORE they are fully formed.	**Repeated ideas.** Concepts generated spontaneously in workshop were similar to ideas we have had since project began. E.g. inputs – ropes, floor pressure sensors, cubby hole, Kinect; outputs – Skype calls, piano, theramin. Is this validation of concepts or anthropomorphism?
					Brainstorming is productive. We knew that already… But still great to have teams thinking about our research questions!	
CONCLUDE				**ACOUSTICS / UNDERSTANDING OTHER**	**JAMMING / BRAIN-STORMING / CROSS-DISCIPLINARY / OWNERSHIP**	**SHARE SKILLS / DISSEMINATION / ANTHROPOMORPHISM**

Further development of concepts explored in workbooks INPUT and OUTPUT.

DISSEMINATION / PUBLICATIONS ARISING

2018 French F, Gupfinger R, Kendrick P. SoundJam 2018: Acoustic Design For Auditory Enrichment. Workshop in the ACI 2018 conference (December 2018, Atlanta). https://doi.org/10.1145/3295598.3314845

5.4 Inputs and Outputs

The following sections elaborate on our research, presenting the results of our enquiries and our design methods and solutions in two workbooks – ***Input*** and ***Output***. As this has been an iterative process, with each design building on evaluation of the previous one, there are many ideas presented and developed in these workbooks. The ideas have all been taken from a conceptual stage to a crafted physical reality that has then been deployed with an animal. Each iteration of a design was critically evaluated, with insights gained from creating each physical prototype informing the subsequent design. Necessarily, the devices are presented in chronological order within each workbook and our annotations are both indexical and analytical. Although the UX design for each device dealt with both input and output simultaneously, the research is presented in separate workbooks to show how each aspect evolved.

Some of the sensors were initially tested with a terrier – Skomer – in lieu of an available elephant, to determine functionality prior to crafting a device to test in the elephant environment at Skanda Vale. Although a dog is a completely different species, there are some notable similarities between dogs and elephants – they both have an excellent sense of smell, they are both naturally curious and willing to investigate new objects, they can both be mischievous and they both have a limited attention span. The advantage of prototyping with a dog is that it is easier to craft at a smaller scale.

5.4.1 Overview of Input and Output workbooks

Table 5 shows how the inputs and outputs are related, as well as which animals tested the device and the location of the testing experience. All initial research and development was done in the London workshop.

TABLE 5: Input and Output Workbook Content

DATE	INPUT	OUTPUT	ANIMALS	LOCATION
2014 - 10		Audio tests	Valli	Skanda Vale
2015 - 03	Pipe / capacitance button	Sine waves	Valli	Skanda Vale
2015 - 05	Push-to-make button	First water pipe	Valli	Skanda Vale
2015 - 10	Pedal button	Aerophone samples	Valli	Skanda Vale
2015 - 12	Vibrotactile buttons	Motor rumbles	Valli	Skanda Vale
2016 - 05	Tactile / ultra-sonic buttons	Second water pipe	Valli	Skanda Vale

2016 - 06	Radio / capacitance buttons	Radio samples	Janu & Machanga	Noah's Ark
2017		Synthesis – Micro:bit	*Dog - Skomer*	Workshop
2017 - 08	Beam-break buttons		*Dog - Skomer*	Workshop
2018 -2019		Synthesis – Processing		Workshop
2018 - 08	Tactile buttons		Valli	Skanda Vale
2018 - 05	Sliders 1 & 2			Workshop
2018 - 08	Ropes		Valli & Lakshmi	Skanda Vale
2019 - 2020	Slider 3	Synthesis – Mozzi	Valli & Lakshmi	Skanda Vale

5.4.2 Researching and Crafting Inputs

The *Input* workbook documents development for *Digital Inputs* and *Analogue Inputs*. Over the course of developing our prototype interfaces, starting with simple versions of digital buttons, we realised that in order to obtain more relevant feedback on acoustic output from the users (elephants), it would be appropriate to offer some analogue controls.

Designing and crafting inputs involved sourcing appropriate materials, based on our predetermined design principles (eco-friendly, natural, safe), and considering how to construct safe and robust artifacts, as well as how to fix them in the elephant enclosure. There was also the challenge of using embedded technology to make the interfaces functional, which required us to use prototyping hardware in the form of microcontrollers connected to various components, such as sensors for capturing interactions. We tried various different technologies over several years, as some were suitable for digital controls and others for capturing analogue data.

This document provides extensive and detailed explanations of how we crafted each prototype. Each new design section starts with a summary of the insights gained from previous work, and shows how these gave us new design goals. Extracts from the relevant blog posts are included, written at the time of development (from http://toys4elephants.blogspot.com/), as well as subsequent information from keepers, after devices were left in place. The crafting of the artifacts and the associated embedded technology is shown in annotated diagrams and photos. Each prototype in this workbook has been tested with an elephant, so we provide stills from CCTV and video taken at the time of testing, as well as links to media files showing video footage of the experience. Finally, each design section finishes with a Table of Insights (as previously described) showing what was learned from this particular Research through Design and Craft iteration and how the main insights are taken forward into the next design stage.

This approach to presenting the design work is also used in the next workbook, focusing on outputs.

5.4.3 Researching and Implementing Outputs

After many attempts, we were confident that it would be possible to construct an interface that was usable for an elephant, but the question remained: Why would an elephant want to use such a device? It was not clear what would hold interest for an elephant other than food. We were still keen to promote playful behavior – meaning behaviour that was not obviously related to biological survival, but might indicate a relaxed and confident demeanour in the elephant. An important feature of play is that it is *voluntary* and that playing is an *autotelic* activity – in other words, that it is sufficiently engaging in itself that no external reward (such as food) is required for players to continue to enjoy performing the playful activity.

Our initial aim was to develop an acoustic toy – one that encouraged free play rather than a structured game with rules, so that it might have similarities with wild elephant object play, yet still offer the kind of cognitive stimulation associated with understanding a new problem space and being able to discriminate between different sounds.

Although using acoustic stimulation as an aspect of environmental enrichment has been attempted with elephants before, in no instances have we found reports of elephants being given control over the audio production, thereby offering them a choice. Wells and Urwin (2008) observed that elephants showed less stereotypic behaviour when they were played 'classical music' and anecdotal evidence (http://www.musicforelephants.com/ ; https://www.thedodo.com/elephant-zoo-classical-music-1206110193.html retrieved 25/09/2020) suggests that some music does have elephant appeal. In these examples, humans selected and played pieces of audio to elephants; in another case (http://www.stevetorok.com/elephant_music_project/ retrieved 25/09/2020), elephants were given the opportunity to control percussive elements, mostly by using their trunks. With this in mind, our goal was to produce an interactive toy that allowed an elephant to make selections (using her trunk) about the kinds of sounds being produced. The fact that audio signals can be produced and altered programmatically meant that they were a practical form of output for a technically enabled system.

Anecdotally (speaking to keepers), when staff have attempted to play different musical sounds to their elephants, the animals have not shown much interest. However, this is an example of the enrichment design being human-centred. Humans appreciate musical harmony but there is little evidence of other mammals finding it interesting. On the other hand, as we mentioned earlier, dolphins have demonstrated the ability to learn new acoustic signals that resemble sounds made by their own species (Herzing et al, 2012), while Snowden, Teie and Savage (2015) report that cats prefer 'species-appropriate' music, based on sounds they hear in infancy.

The Output workbook documents our investigation into both *Tangible Output* and *Auditory Output*. The elephant keepers believed that elephants would find it enriching to be able to control a water supply. Thus, the research initially focused on exploring a different form of output when we attempted shower controls, away from playful systems, and towards a more utilitarian interface design. We categorized the output for these devices as Tangible.

Input

CONTENTS

One of our first challenges was to design some input devices that would work for an elephant. To be fit for purpose they had to be safe, robust, effective, easy to use and also possible for an elephant to comprehend.

This workbook describes the evolution of those designs, starting with digital buttons that act as a simple functional input offering a choice – ON or OFF – and moving on to some analogue designs, aiming to offer a graduated control system.

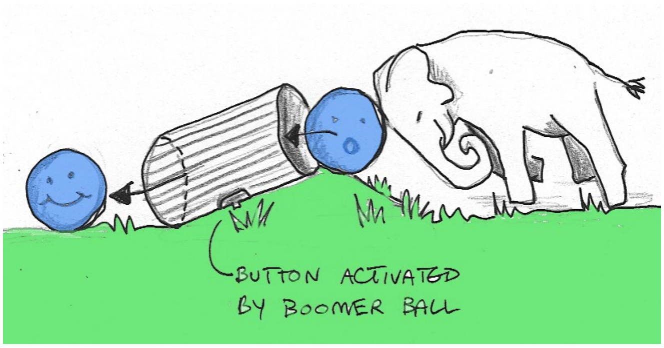
The associated outputs are explained in the OUTPUT workbook.

Input: Digital

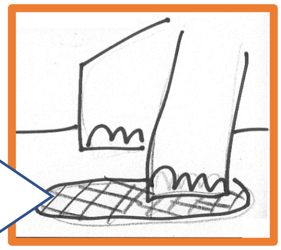
RATIONALE & EARLY CONCEPTS

Here are the early concepts which informed the subsequent designs. There are 2 interdependent parts to each input design – the physical interface and the electronic sensing that enables it to work – in order to capture the input and map it to an output in order to control a system. The output development is presented separately in the subsequent workbook.

Some of these ideas attempted to use audio as either feedback or output…

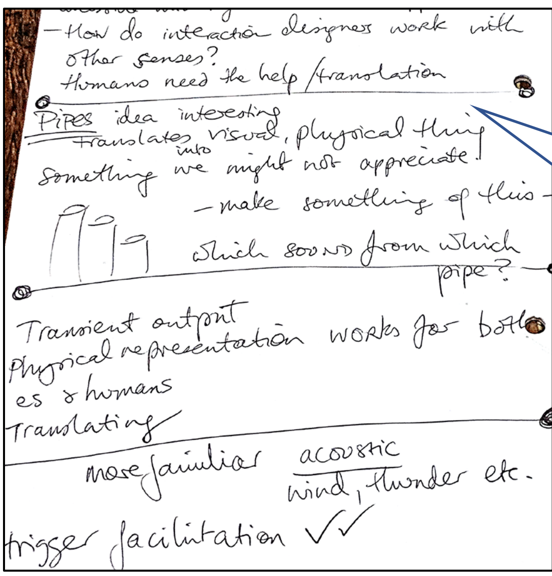


Foot button – easy to use but difficult to manufacture: expensive, heavy, messes with substrate. Would she even notice it was there? Heavy duty pressure sensor?



Some concepts were never attempted because of expense (e.g. Giant Boomer ball costs $325)

Elephants like to explore small places with their trunks – probably looking for food – here it's Zola at Colchester Zoo feeling the crevices in some rocks…


– How do interaction designers work with
other senses?
Humans need the help / translation
Pipes idea interesting
Translates visual, physical thing into
something we might not appreciate!
– make something of this –
which sound from which pipe?
Transient output
Physical representation works for both
es & humans
Translating
more familiar acoustic
wind, thunder etc.
trigger facilitation ✓✓

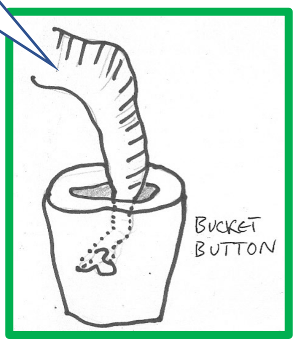
Page from notebook showing some sketches for PIPE BUTTONS that could trigger acoustic output. These were a simple alternative to buckets and this concept was the first one to be taken to production – see next page…

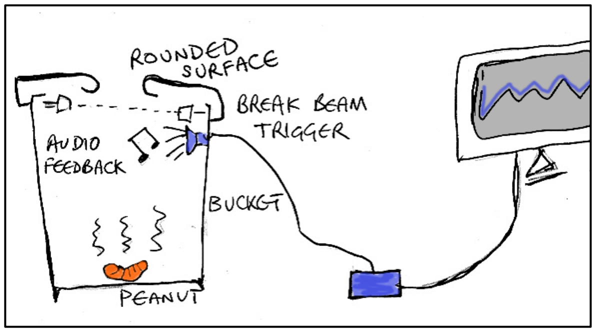
CHALLENGE – fixing pipe securely to wall or balcony; pipe extends away from enclosure and trips you up?

RATIONALE & EARLY CONCEPTS

Early concept inspired by Colchester elephants always dipping their trunks into buckets for bits of cabbage.

However, association with food is not appropriate – food such a strong motivator that it would be impossible to judge if any other output held interest.





		INSIGHTS					
DEVICE	**Date**	**Testing - tech - sensors**	**Elephants - materials - dimensions**	**Output**	**Location**	**People**	**OTHER**
WHERE DID WE START?		**Hidden sensor that captures proximity or touch - CAPACITANCE SENSORS**	**Experts recommended large pipes or buckets for trunks to explore - DRAIN PIPE**	**Testing simple acoustics generated by micro-controller - SINE WAVES**	**Safety first - trunk tip access - try BROWSE HOLE**	**Build prototype at home, take tools to Skanda Vale to WORK WITH KEEPERS on**	

So our starting point was to design a **pipe button** constructed from an old drainpipe so that our elephant tester could put her trunk inside. We decided to have a sensor hidden in the pipe and to trigger some simple noises when the sensor was activated. **Capacitance** sensing seemed to be a good first choice, because simple sensors are relatively easy to make from household items, so we could design them to fit any shape. They can be used as either touch or proximity sensors, depending on calibration – so would potentially be good for a rough test of trunk interest.

Because of concerns about elephants' destructive capabilities, a **browse hole** seemed to be a good choice for locating the device, because it restricted her to trunk-tip access and reduced the opportunity to cause damage. A browse hole is a common feature in an elephant barn – basically a hole in the wall with a container mounted behind it that can hold some hay.

Examples of browse holes at Dublin Zoo, Twycross Zoo and Blair Drummond Safari Park.

MARCH 2015: PIPE BUTTON / CAPACITANCE

BLOG POST: 12 March 2015
Making the first prototype buttons

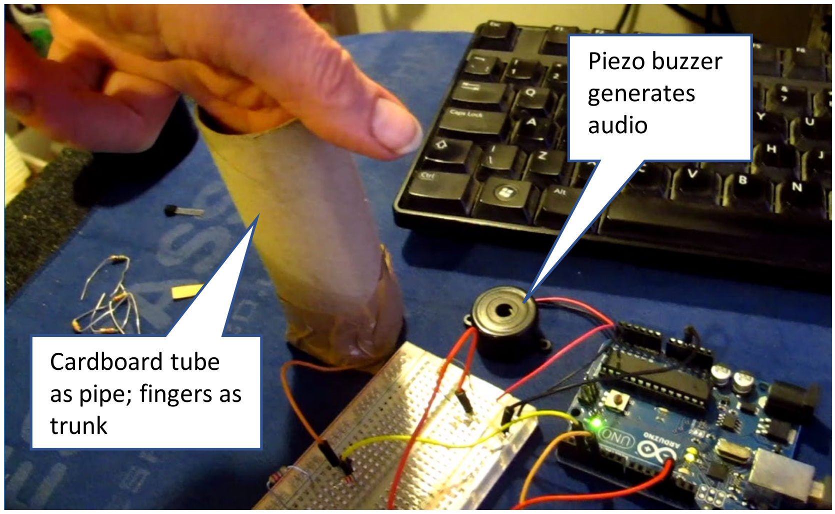
AIM - construct homemade elephant buttons, made from pieces of drainpipe mounted on wood.

The idea is to make lifesize buttons that we can test with Valli, using any materials lying around in the garden shed.

I hope that Valli will investigate the pipes and in doing so, approach capacitance sensors mounted at the base - these are made from tinfoil and plywood sandwiches and can be calibrated to act as inputs before they are actually touched.

As she approaches each button with her trunk tip, a different tone is produced from a piezo buzzer. Using a tiny piezo buzzer, it is not possible to generate the low and interesting sounds (didgeridoo) that we tested on our last visit.

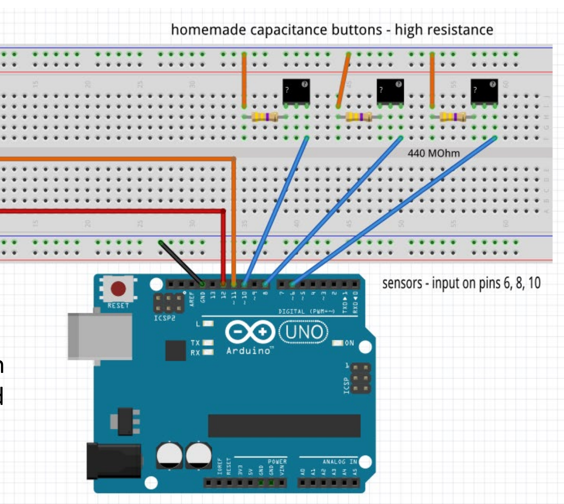
Here's an example Fritzing sketch, showing how simple it is to make these kinds of sensors:



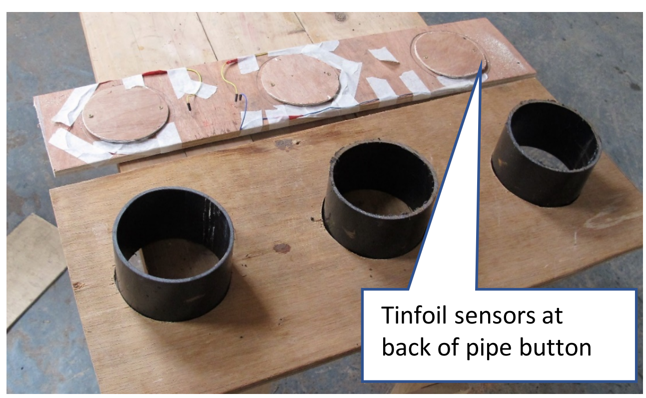
Testing homemade capacitance sensors – set of 6 buttons constructed from tinfoil

fritzing

https://fritzing.org/home/
Open-source software for documenting hardware



Circuit diagram shows Arduino interfacing with capacitance sensors and audio output



MARCH 2015: PIPE BUTTON / CAPACITANCE

BLOG POST: 20 March 2015
AIM - to see if Valli can use pipe buttons.

The Skanda Vale elephant barn has some useful browsing holes, so we closed one and dismantled the original frame, then fixed the button system in place. It was soon obvious that the 20cm pipe I had used was too small for Valli's trunk, so Brother Peter and I resolved to build a bigger version the following day.

We found some more wood and larger dimension pipe and made a simpler 2 button version for Valli to try.

Brother Stefan coaxed Valli to probe the hole using a piece of banana at the end of the button, which meant that she obviously continued to search the buttons for more food treats. This meant we couldn't show that she was interested in the sound being produced, but it gave us a good idea of the practicalities of future button production.

Future plans to try and make a shower control for Valli, so she can activate the shower by herself from inside her barn.

MEDIA LINKS
- Testing pipe buttons in elephant barn
  https://vimeo.com/364638646
- Valli explores the zone
  https://vimeo.com/364639219

The pipes are too narrow for her trunk

MARCH 2015: PIPE BUTTON / CAPACITANCE

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
WHERE DID WE START?		**Hidden sensor that captures proximity or touch - CAPACITANCE SENSORS**		**Experts recommended large pipes or buckets for trunks to explore - DRAIN PIPE**	**Safety first - trunk tip access - try BROWSE HOLE**	**Build prototype at home, take tools to Skanda Vale to WORK WITH KEEPERS on location**
PIPE	Mar-15	**Early warning of capacitance sensing interference with 3 buttons.** Use a different sensor technology – push-to-make button seems simple. What can go wrong?	Acoustic	**Valli's trunk is bigger than you imagine.** Do some measurements and ensure that subsequent button is large enough – choice of shallow plastic bucket.	**Avoid using a browse hole.** Strong association with food means she will always trigger button BECAUSE she's looking for snacks. Need to find another suitable location – trunk-tip access, easy to fix.	**Peter's construction skills.** Aim to come with a ready-to-use prototype so as not to impact too much on keeper time.
		Calibration impossible in lab for trunk in field. Capacitance of trunk is very different from human hand? Would always need to be re-calibrated.		**Potential interface design.** Valli could definitely use a pipe as a "button".	**Requires a lot of trust** - Valli can't see what's beyond the browse hole, so she has to rely on her other senses and only receives feedback when she has already triggered the device. If she didn't enjoy the output, this might be alarming. To consider.	**Don't let Stefan use bananas!** Clarify appropriate methodologies for testing prototypes with animals – emphasise that we want to avoid food motivators and allow Valli to learn how to use button herself.
					Can she even hear beeps on other side of wall? She probably can, but may not associate them with her actions. Provide more obvious feedback?	**Keeper enthusiasm for shower control.** Stefan is very keen to test shower controls, so we'll move forward with a button that triggers water – a more obvious output than beeps and also supporting collaboration and teamwork.
CONCLUDE		**PUSH-TO-MAKE**		**PLASTIC BUCKET**	**NOT BROWSE HOLE**	**KEEPER TIME / FOOD / SHOWER**

Although capacitance sensing worked well for one button, and could also support a graduated input, there was interference between pipes when we tried to add more controls, so the signal was erratic. We also thought it might be confusing for the elephant because how would she know whether she had triggered an output if the sensor was triggered without even touching it? **Push-to-make** buttons are a staple of electronic tinkering, so let's scale them up!

Stefan suggested mounting something on underside of balcony (made of wood, easy to screw into) so we went for a shallow **thin plastic bucket** rather than a solid pipe.

As the keepers were motivated to generate a shower control, we experimented with water as an output instead of noise.

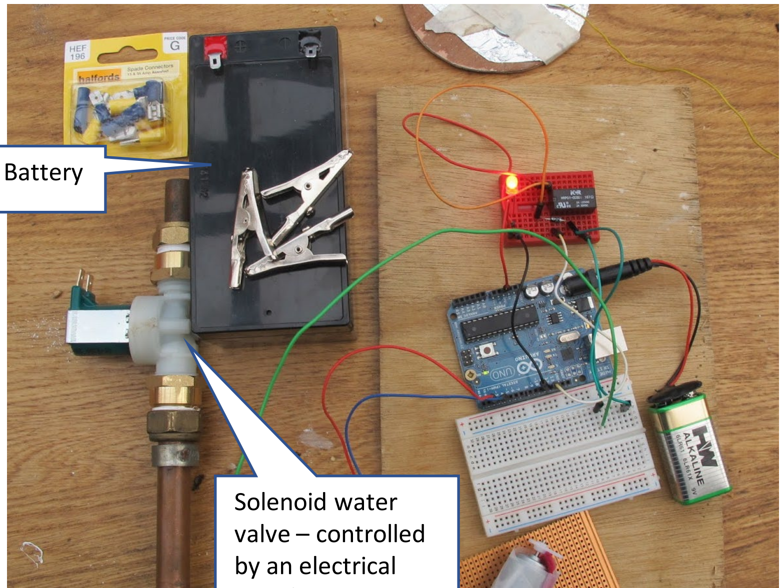
Input: Digital

MAY 2015: BUCKET / PUSH-TO-MAKE

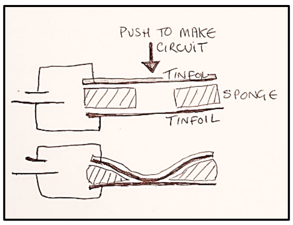
BLOG POST: 14 May 2015
AIM - to control water supply using elephant button.

Input is a large push-to-make button (constructed from layers of tinfoil and plastic with foam sandwiches in the middle - similar to a dance mat). Output is a 9V DC solenoid water valve connected to Arduino via a relay switch. The valve intercepts water supply from a hosepipe to a shower head.

System works - the 9V battery required to power the solenoid is pretty hefty. The main difficulty was finding suitable connectors for all the pipework components.

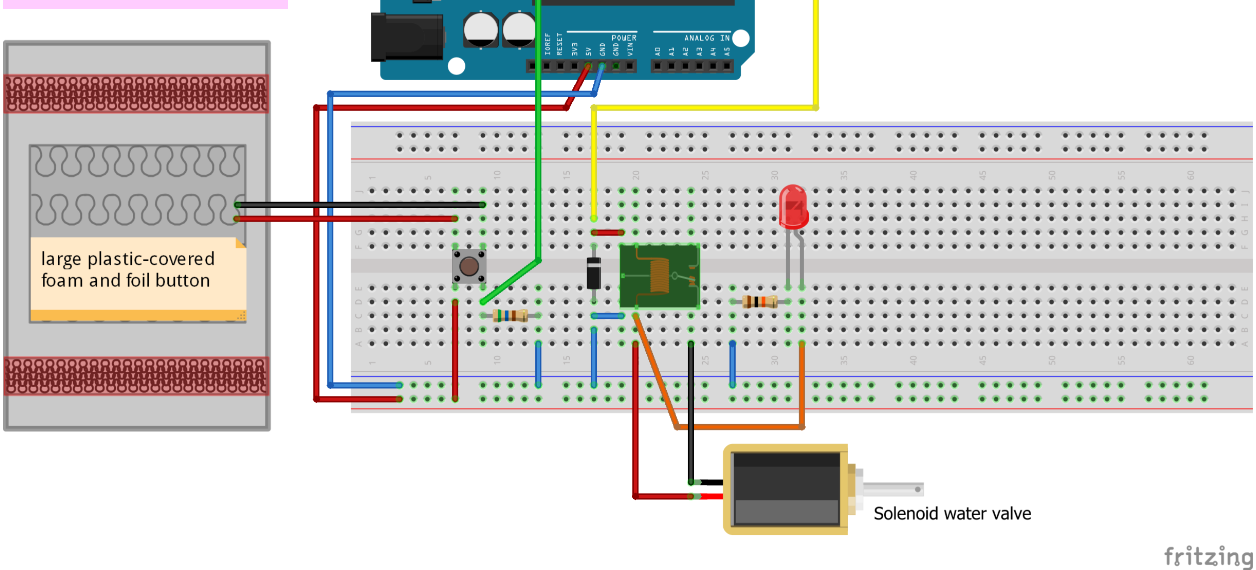


Tinfoil and foam sandwich – when you press the top, an electrical connection is made – fixed in a plastic basin

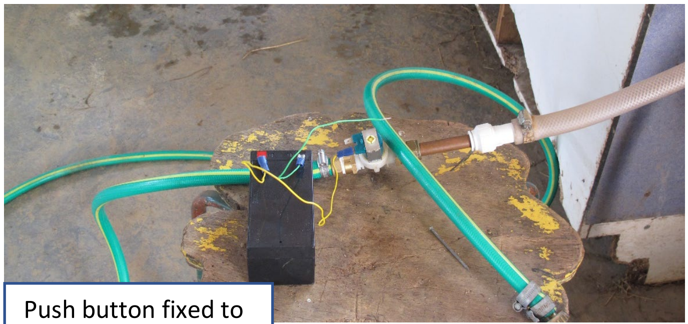


Requires light pressure

What it looks like



MAY 2015: BUCKET / PUSH-TO-MAKE



Push button fixed to ceiling = beneath floor of balcony

BLOG POST: 4 July 2015
AIM - to meet Valli and test out the water valve system.

We fixed the button to the ceiling next to Valli's enclosure so she could reach it with her trunk.

On the floor above, the button was connected to an Arduino input pin. The output activated the water valve via a relay switch, sending a strong spray of cool water along a hosepipe and down onto the rubber mat where Valli usually has a wash.

The water was on for a 30 second burst, then had to be re-activated. She was persuaded to use the button a few times, but moved sharply away from the water spray - obviously not a strong motivation!

Brother Stefan will plumb in the pipework properly so we can test different interfaces that she might (or might not) like to use.

MEDIA LINKS
- Testing bucket button in elephant barn
  https://vimeo.com/406352738

Valli can't see the device, so Stefan and Peter try to show her where it is

She can use it independently, but probably only does so in the hope of another banana…

The button only needs a gentle firm push, but there's no feedback built into the device to let her know if she triggered it or not.

Input: Digital
MAY 2015:
BUCKET / PUSH-TO-MAKE

		INSIGHTS				
DEVICE	Date	Testing - tech - sensors	Output	Elephants - materials - dimensions	Location	People
START		PUSH-TO-MAKE		PLASTIC BUCKET	NOT BROWSE HOLE	KEEPER TIME / FOOD / SHOWER
PUSH-TO-MAKE	May-15	**Offers no innate feedback (like a switch that has 2 positions).** Let's make a traditional switch like the ones humans use – can we find a giant pedal ?	Water	**Plastic bucket too flimsy.** Use more robust materials for creating prototypes – wood? Benefit that it is a natural material for an elephant to manipulate.	**She can't see it, therefore doesn't know it's there.** Using different modalities – not enough to smell and touch. Find a location that is visible and see what happens.	**Keepers still keen to train her to use – palming apple chunks.** Continue trying to persuade keepers to allow Valli to discover device by herself and work out how to use it independently!
				Shock of water probably not connected to button for Valli (cognitive). This is a mapping problem – attempt to reduce delay between trigger and output. At present she is unaware of having control over system.	**Awkward to reach – unlikely to explore here, no previous rewards.** Find a location she can reach easily with trunk tip. The balcony railing seems as if it might be suitable – a device could be placed high up so she can't use full strength. Can we attach to the wire netting?	
CONCLUDE		PEDAL SWITCH		USE WOOD	BALCONY	FOOD / METHODS

Now we thought the elephant would not know whether she had triggered an output because the interface offered no physical response. Human light switches have an obvious affordance, in that they click softly and also move to a new position when triggered (as well as being visible and located within easy reach). The output is not in proximity to the switch, but the effect is instantaneous.

So we decided to try a "traditional" switch, but scaled to elephant size – deploying an old sewing machine **pedal**, hacked so it provided a digital output (on/off). It needed to be housed in something robust – 10mm ply – and Stefan suggested attaching to balcony fence. This required 200mm bolts and a solid back plate.

For this test, we reverted to offering acoustic output, partly because it was simpler to set up and partly to fulfil original objectives.

DISSEMINATION

2015 French F, Mancini C, Sharp H. Interactive Toys for Elephants. *CHI Play 15*; Published in Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play. https://dl.acm.org/citation.cfm?doid=2793107.2810327

OCTOBER 2015: PEDAL / PUSH-TO-MAKE

BLOG POST 17 Oct 2015
AIM - to catch up with Valli and test a new kind of button that provides some tactile feedback.

We used a giant button made from a sewing machine foot pedal, which is essentially a potentiometer on a spring. The foot pedal would normally provide a variable output, but I simplified it to ON/OFF.

We created a wooden housing that surrounded the case so that Valli wouldn't be able to grasp the button with her trunk, only push it. The button was bolted to the fence across the balcony that overlooks her space in the elephant house. Wire out the back (on the non-elephant side) connected Arduino to my laptop and activated a Processing sketch that played a one second audio sample.

We tested a low rumble, didgeridoo, tuba, double-bass and contra-bassoon.

Valli was interested in exploring the shape and contours of the new button, but appeared reluctant to push it.

Brother Stefan thinks that an alternative embedded sensor that just requires touch will be more successful with acoustic stimulation. I designed a prototype set of buttons using LDRs as sensors, but we didn't have time to test on this occasion. I did another quick survey of the space so we could construct suitably sized panels for containing controls along the fence.

MEDIA LINKS
- Testing giant pedal button in elephant barn
  https://vimeo.com/146186217

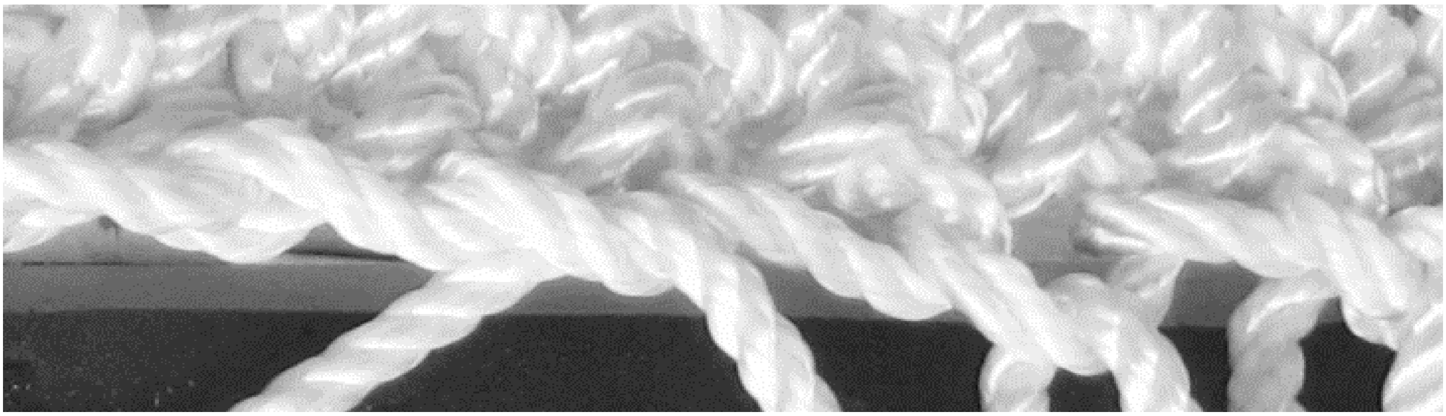
OCTOBER 2015: PEDAL / PUSH-TO-MAKE

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
START		**PEDAL SWITCH**		**USE WOOD**	**BALCONY**	**FOOD / METHODS**
PEDAL	Oct-15	**Switch** moves, but only if Valli presses it. No pressing, so why not try haptics? Cue vibrotactile button.	Acoustic	**Something designed for a human but made bigger isn't going to work.** Anthropomorphic – start again and look at elephant behaviour.	**She saw it and immediately started to investigate.** Validation of making the device visible – keep this.	
		Back to hidden sensors - let's try IR -		**Elephants don't push things – they explore and pull.** You don't push leaves off a tree. Rope? But tricky to capture the movement with a sensor…	**Balcony rail is a good location – easy to fix, she can see, we can adjust.** Validation of location – keep this.	
		Output undesirable and probably not connected to button (cognitive). Avoid surprises, avoid delays. For Valli in this context, feedback is the same as output – how to distinguish?		**She was interested in exploring gently and carefully with her trunk.** Interesting to watch and Valli clearly curious to feel surface. Unexpected behaviour – playtesting with user.		
CONCLUDE		**VIBROTACTILE INFRA-RED BUTTON**		**TACTILE INTEREST**	**KEEP BALCONY**	

The elephant's response made us decide to revert to using hidden sensors so we could be sure to track her interaction and capture it digitally. Next time we would try infra-red by repurposing a motion sensor (typically used to dynamically switch on lights when someone enters a room) by removing the diffuser and focusing it on an area just in front of the button.

Still keen to provide instant tactile feedback (like the moving switch), we started to experiment with vibrating motors, such as the type found in mobile phones. We also scuppered a simple motor by adding weight to one side of the rotating arm, to give an alternative vibration – which also made a noise, probably making the accompanying audio redundant.

Valli's interest in feeling the pedal gave us the idea to offer a more interesting surface on the button, so we experimented with knitting textiles using a variety of ropes and string…

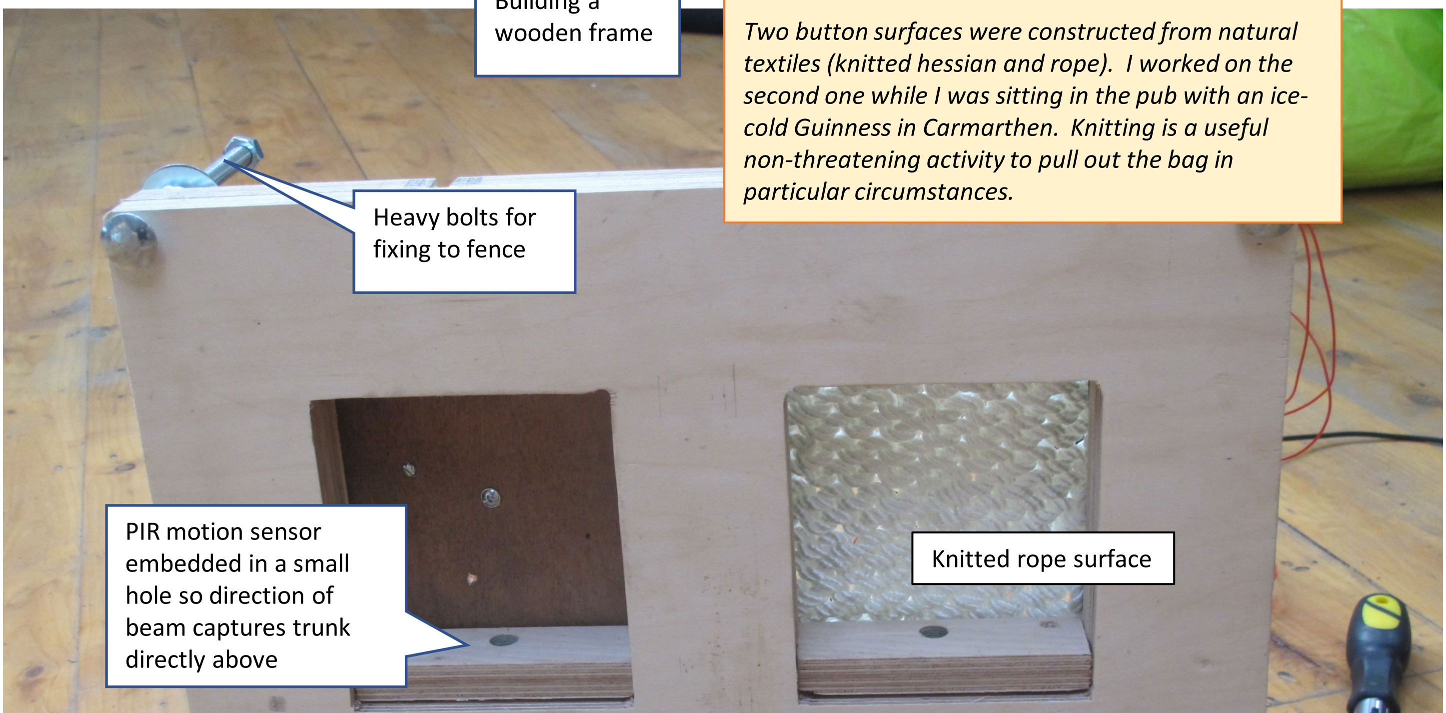


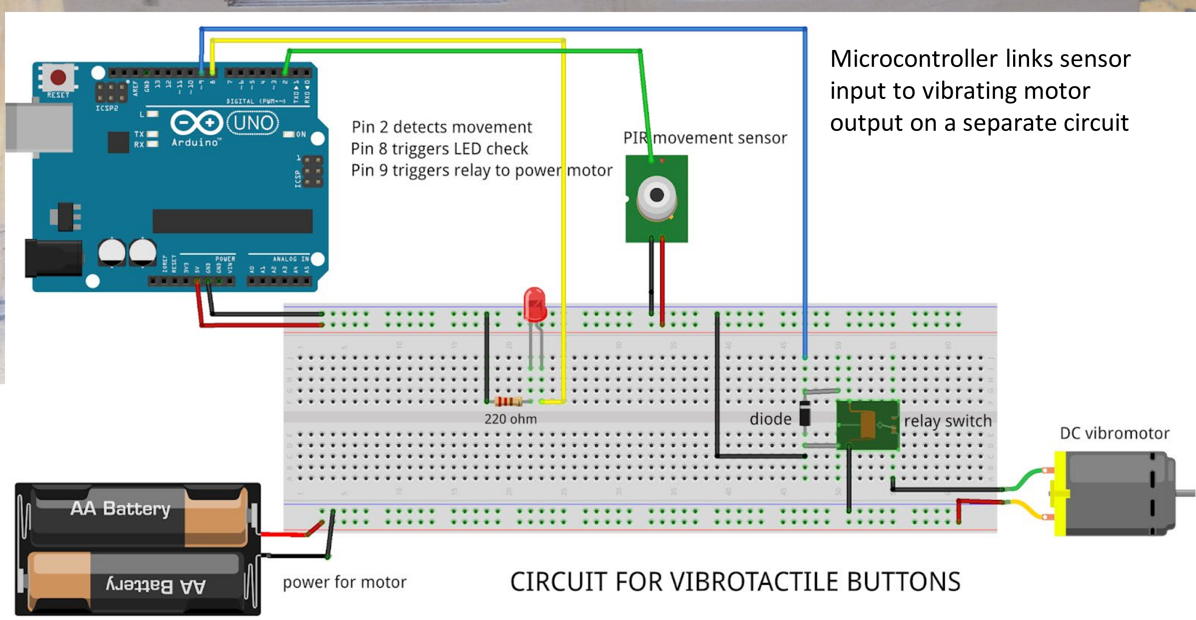
DECEMBER 2015: VIBROTACTILE / IR SENSOR

BLOG POST: 9 Dec 2015
Vibrotactile controls
December in Skanda Vale - more button tests…
Because there were some problems with interference when using capacitance sensors in close proximity (for the earlier pipe buttons), for this test we used PIR (passive infra-red) technology to sense an approaching trunk.

The PIR sensors are embedded in the wooden frame, which was bolted high up on the balcony so that Valli could only use her trunk tip to touch it.

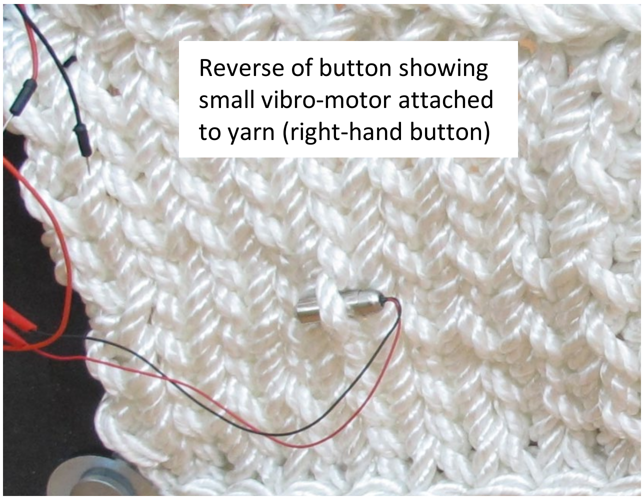
Two button surfaces were constructed from natural textiles (knitted hessian and rope). I worked on the second one while I was sitting in the pub with an ice-cold Guinness in Carmarthen. Knitting is a useful non-threatening activity to pull out the bag in particular circumstances.





CIRCUIT FOR VIBROTACTILE BUTTONS

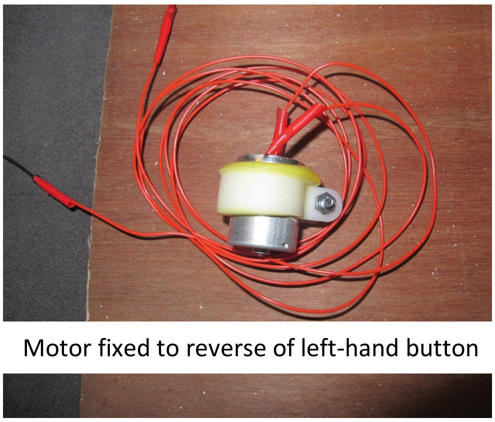
DECEMBER 2015: VIBROTACTILE / IR SENSOR



Reverse of button showing small vibro-motor attached to yarn (right-hand button)

9/12/2015
These buttons both offered interesting textured surfaces to explore and activated audio samples, as well as providing haptic feedback in the form of vibrating motors behind the contact area.

The keepers agreed that Valli was able to use these buttons successfully and seemed interested in exploring them. She spent some time feeling both activated buttons, which had distinct vibration patterns.



Motor fixed to reverse of left-hand button

Valli places her trunk inside the button areas. The tactile quality seems to hold more interest than the audio output generated

This was a breakthrough button, in that the technology worked, but also because it offered some insight into a new area – haptics.

MEDIA LINKS
- Testing vibrotactile button in elephant barn
  https://vimeo.com/365148828

DECEMBER 2015: VIBROTACTILE / IR SENSOR

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
START		**VIBROTACTILE INFRA-RED BUTTON**		**TACTILE INTEREST**	**KEEP BALCONY**	
VIBRO-TACTILE	Dec-15	**Hidden sensor works well.** Next time we will try an ultra-sonic sensor, also hidden. It should offer the possibility to capture a variable input as it gives readings based on distance.	Acoustic	**Valli likes haptics – new direction?** Too many possible new directions – stick to Plans A and B (audio and water output) but continue with a tactile button.		**Stefan still too keen to train.** Not quite sure how to approach this, except to go with his ideas for time-being.
		Motors use power. If we're driving a pump for water supply, keep vibration out of system.				**Keepers keen to keep trying a shower control.** Let's try another water system interface.
		Still no connection between output and action? – but vibration is more immediate and co-located than anything else we tried so far. Feedback = output.				**Knitting is a conciliatory activity in a male-dominated environment.** Bring existing design and practice into the mix – crafting offers low-tech opportunities for enhancing the user experience by considering aesthetics and applying easily. Also a novel dimension and showcase of personal skills. Find some suitable yarns.
		Rumbles. Also, we think feeling conflates with hearing - motor rumble.				
CONCLUDE		**ULTRA-SONIC**		**TACTILE**	**KEEP BALCONY**	**WORKING TOGETHER - TRY WATER AGAIN**

We decided to try **ultra-sonic** sensors to obtain a distance reading – more experimentation to find what would be most suitable, as there was nothing wrong with the IR. If the ultra-sonic sensors worked, they could theoretically then be deployed to offer an analogue input.

We built on the apparent interest in a textured surface by using a **tactile** feature again, but only the button surface not a vibrating motor. We made another attempt to control a water supply at the request of the keepers and this involved using a solenoid valve (like an electronic "tap" on the water pipe) which required 12V. It couldn't be driven through the microcontroller but required its own power supply which was mediated by the Arduino.

Electronics and hardware prototyping can sometimes feel like a gendered field of interest – "making for boys" – whereas "soft" crafts (creating or using textiles) are traditionally associated with females. Blending knitting with embedded tech can ease the transition between territories.

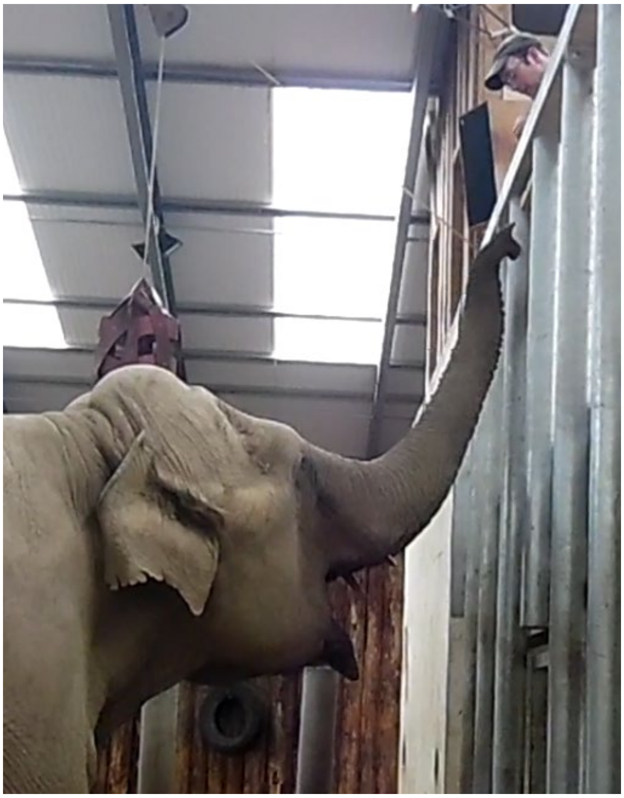
DISSEMINATION

2016 Webber S, Carter M, Watters J, Krebs B, Mancini C, Sherwen, S., French, F., O'Hara, K. HCI Goes to the Zoo. Workshop in the *2016 CHI* Conference. https://dl.acm.org/citation.cfm?doid=2851581.2856485

2016 French F, Mancini C, Sharp H. Trunk-enabled Toys. Presented at *CHI 2016* Workshop: HCI Goes to the Zoo.

2016 French F, Mancini C, Sharp H. Playful UX for Elephants. Presented at Symposium: Animal-Computer Interaction at *Measuring Behavior 2016*.

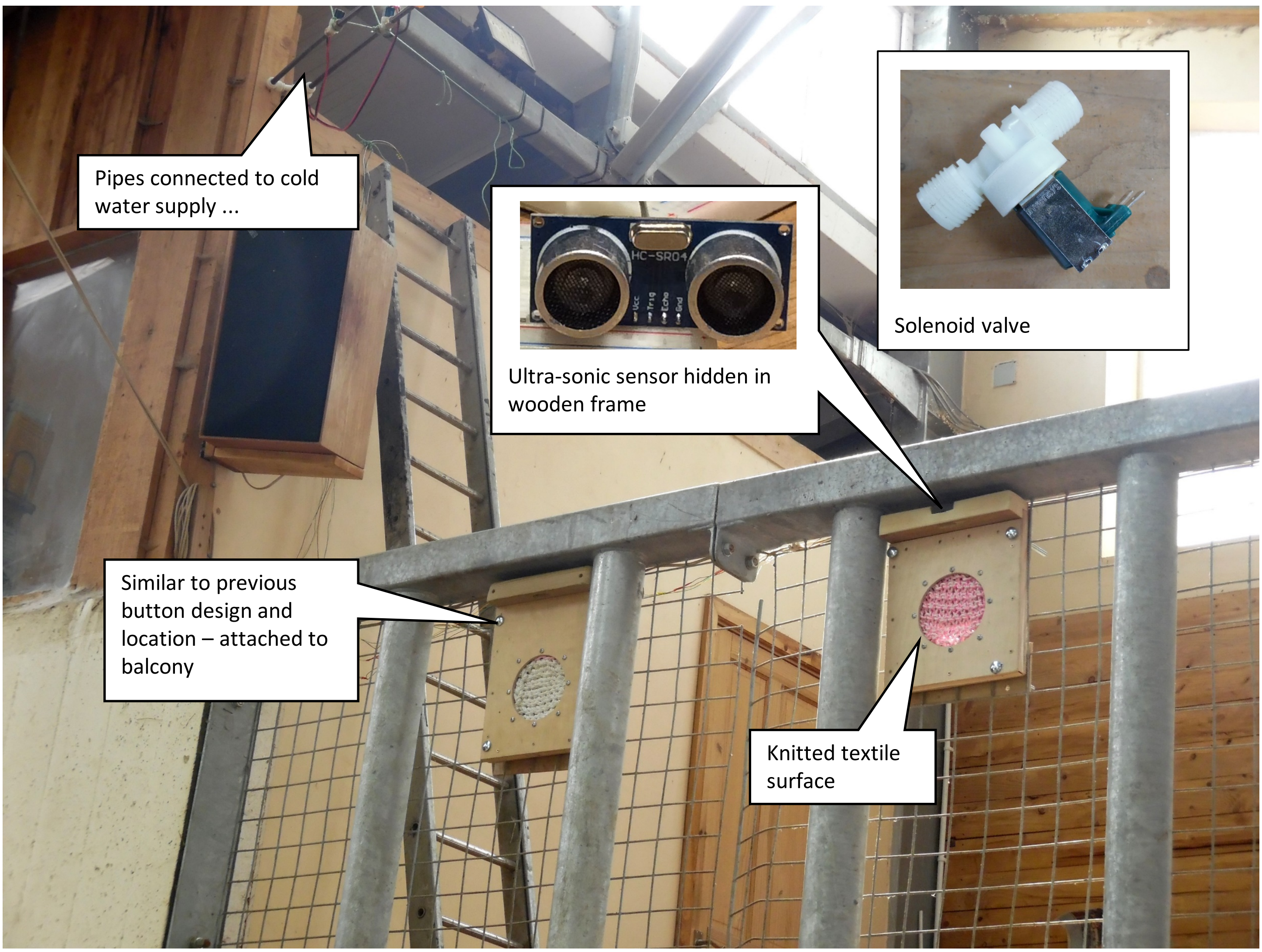
MAY 2016:
TACTILE / ULTRA-SONIC SENSOR



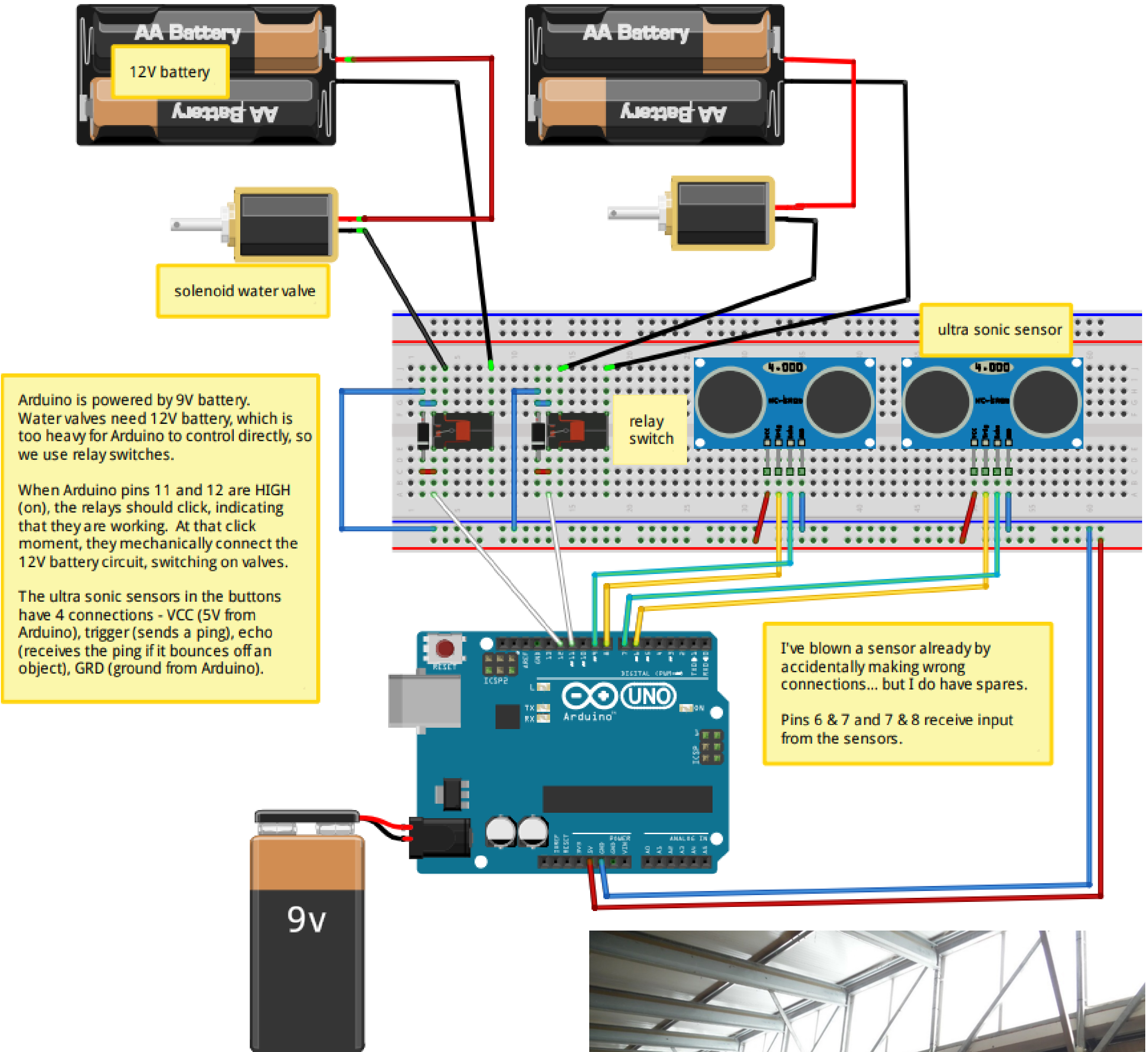
BLOG POST: 12 May 2016
This week's visit was focused on making Valli's shower controls work.

I had pre-assembled the textile buttons, fitted with ultra-sonic sensors, but we needed to fix solenoid valves to the water pipes and wire everything up to the micro-controller.

Brother Stefan had put aside some time to help with the plumbing and everything seemed to work... until the water pressure dropped. The Skanda Vale water supply is pumped from a bore-hole, rather than mains, so the pump only kicks in when the pressure is becoming low. Unfortunately, the valves are designed to work at full mains pressure only. We need to replace with latching valves.



MAY 2016:
TACTILE / ULTRA-SONIC SENSOR



12/5/2016
After I left, Brother Stefan told me that Valli had managed to pull out some of the wires from the Arduino, which was very resourceful of her, since they were on the other side of the balcony rail. Presumably she could grasp the trailing wires through the wire netting. Brother Danny is keen to experiment with Arduino, so I'm sending them the sketch (well-commented) + a Fritzing circuit diagram + 2 new latching valves. Hopefully, they will be able to make some independent progress with showers and I will focus on acoustic and haptic enrichment.

Brother Stefan fixing the water pipes above the enclosure – water jet coming out

MEDIA LINKS
- Testing shower system with Valli – avoiding: https://vimeo.com/406585812
- Triggering shower: https://vimeo.com/406585860

MAY 2016:
TACTILE / ULTRA-SONIC SENSOR

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
START		**ULTRA-SONIC**		**TACTILE**	**KEEP BALCONY**	**WORKING TOGETHER - TRY WATER AGAIN**
TACTILE - ultra-sonic	May-16	**Complex system – lots can go wrong – relays can fail, water pressure can fail, batteries run out because sensors use a lot of juice pinging all the time.** KIS – Keep it simple. Change technology when there is no mains power – what about trying capacitance again?	Water	**Wooden frame and bolts on fence work well.** Great, keep this design.	**Wires on balcony side of fence are accessible; so are pipes at a height of over 4m.** We didn't think Valli could reach wires or pipes, so we underestimated her ability to manouevre when she is motivated. Implications for safety.	Meanwhile Noahs Ark Zoo have expressed interest in deploying our **elephant radio** concept...
		Water pressure out of my control – need different valves. Another lab v. field situation. Would be good to have time to test in situ before deploying with elephant.		**Valli can be destructive when no-one is around.** It's a good idea to leave system in place overnight to see what she will do to it. She obviously modifies her behavior in presence of keepers.		
		Delay between trigger and valve releasing and then water travelling along pipe – no obvious connection therefore. Mapping issue – the valve needs to be nearer end of pipe.				
CONCLUDE		**KIS**		**WOOD + BOLTS + LEAVE IN PLACE**	**KEEP BALCONY**	**ELEPHANT RADIO**

Frustrating experience because the water valve would only function under mains pressure and the water supply to the elephant shed was on an independent pump that switched on and off automatically when the pressure dropped below a threshold. Except the threshold was less than mains pressure, so the valve stopped working. The keepers decided to give shower controls a rest for a while, due to the elephant's reluctance to trigger an overhead water supply and her subsequent vandalism of the system!

Another captive elephant facility expressed interest in working with us, as did Lisa Yon from EWG and one of her graduate students, Ashley. Lisa and Ashley's interest was also in acoustic enrichment, so the focus moved from Wales to Bristol temporarily. This time we decided to craft with solutions that had worked in the past but to make an **elephant radio** offering a choice of sounds so we could do some preference testing. The plan was to then return to Valli and give her an opportunity to also try the device.

EXCERPTS FROM EMAIL TRAIL RELATING TO NAUGHTY ELEPHANT

16/5/2016
Hi Fiona Thanks for the notes, they have come in very helpful as Valli managed to grab some wires and pull them out! BrDanny and myself put it back together. Pls send Arduino sketch BrDanny is very interested to play with it. I will check if BrAlex wants play with it as well.
... She got the cable from the buttons to the arduino board.

20/5/2016
The colours are messed up as Valli ripped the cables into bits.

22/6/2016
Hi Fiona Valli got hold of the pipes and had a lot of fun with it!!

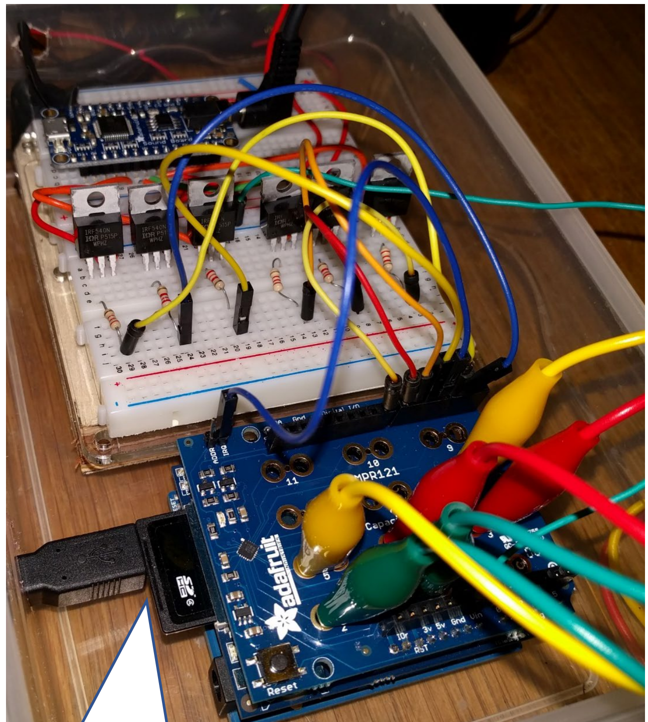
MAY 2016: RADIO / CAP SENSOR

BLOG POST: 30 June 2016
This month has been all about designing and constructing the elephant radio system that we plan to install at Noah's Ark Zoo. It's tricky, because there are quite a few considerations to take into account. There won't be a mains supply, so one of the challenges is designing a system that can be battery powered for a week. This means I can't use PIR or ultra-sonic sensors, which use up a lot of juice, pinging all the time while they wait for an interrupt.

I plan to do some data-tracking, but the data logger shield (https://www.adafruit.com/product/1141) uses many of the Arduino pins, so I need a system that works on top of this simultaneously.

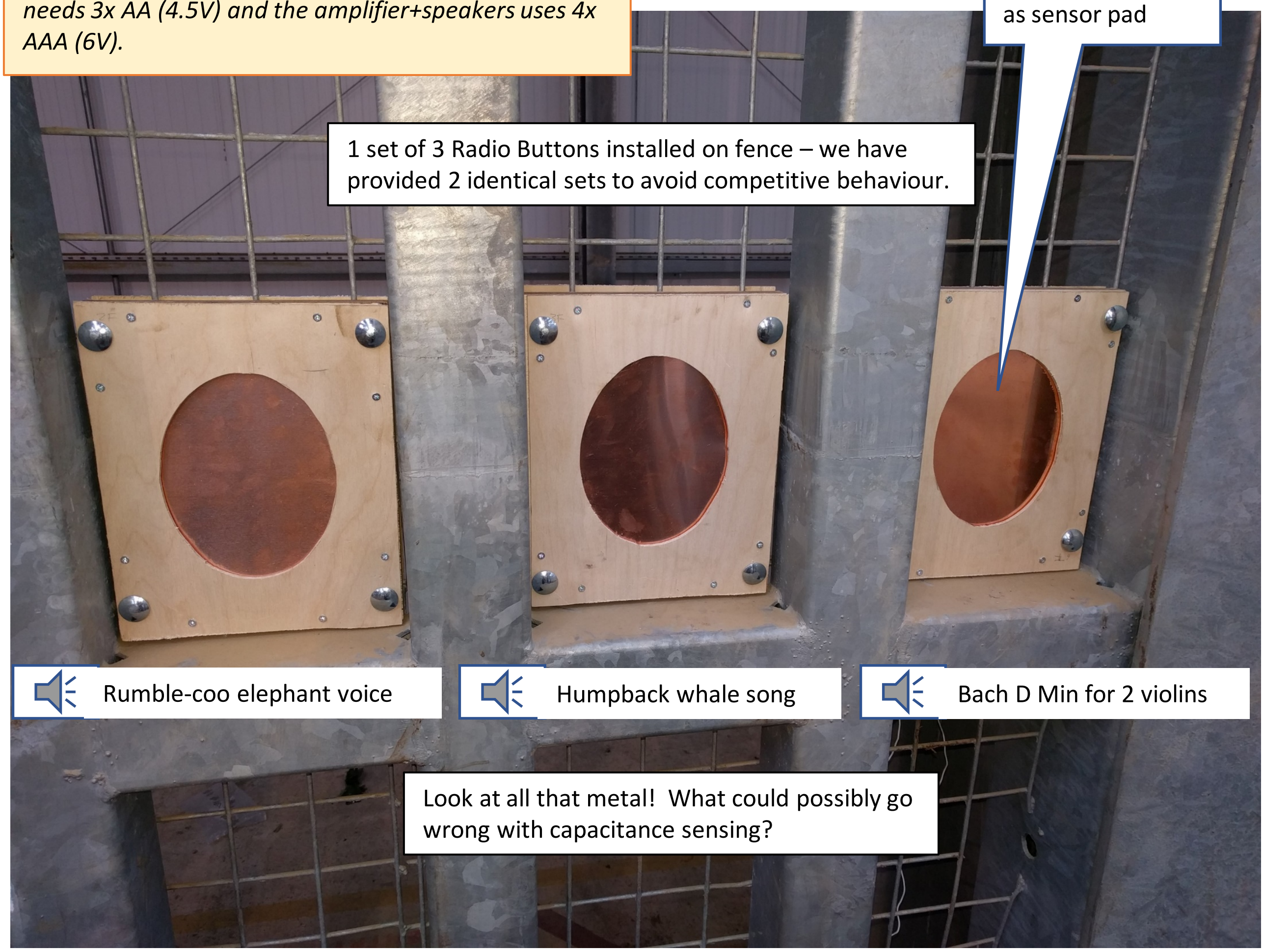
I opted to go for capacitance sensing again, this time using a shield (https://www.adafruit.com/products/2024) that re-calibrates every time it is reset and also manages some simple filtering of the signal to avoid interference. I was able to add both shields to Arduino Uno and use six sensors to trigger separate audio files from a simple sound board. (https://www.adafruit.com/products/2220)

The system relies on 3 different charging systems - the Arduino uses a USB-5V/1A bank; the sound board needs 3x AA (4.5V) and the amplifier+speakers uses 4x AAA (6V).



Another complicated system (!) using capacitance sensing

Copper plate used as sensor pad



1 set of 3 Radio Buttons installed on fence – we have provided 2 identical sets to avoid competitive behaviour.

Rumble-coo elephant voice

Humpback whale song

Bach D Min for 2 violins

Look at all that metal! What could possibly go wrong with capacitance sensing?

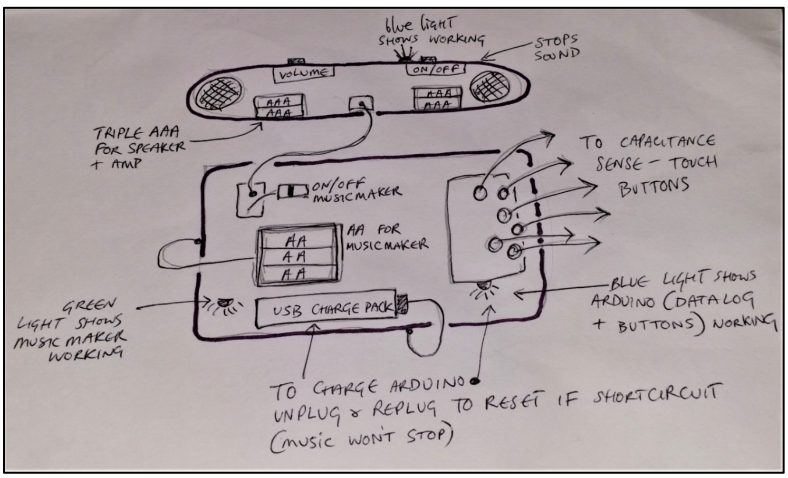
MAY 2016:
RADIO / CAP SENSOR

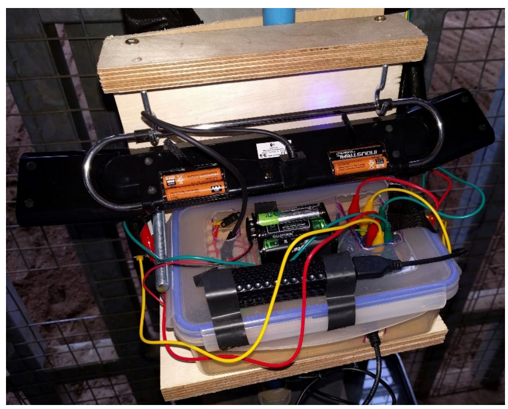
BLOG POST: 7 July 2016
Noah's Ark audio installation
Ashley (Bryant) and I installed the buttons inside Noahs Ark elephant enclosure between 11-1, when the animals are kept outside.

Initially, the system was working, and we were able to film the elephants coming into contact with it for the first time. However, although it was clear they could use the interface and were naturally drawn to explore the surface, the device did not work consistently. It stopped, and needed to be reset a few times, but then when triggered, one of the buttons played continuously before stopping (it is supposed to only play when there is contact with the sensor). I suspect that the large amount of metal in the enclosure is having an effect on the cap sensing.

I left a diagram to show keepers how to change batteries and switch system off if it stopped working properly, although I asked them to keep the Arduino charged so we could continue to use the datalogger.

Ashley helping fix buttons





Complex system for keepers to maintain

MAY 2016: RADIO / CAP SENSOR

BLOG POST: 8 July 2016
At first, Janu and Machanga walked straight past the elephant radio, and we realised it was installed above eye-level. However, when Janu moved across the enclosure and looked back, he saw there was something new and came immediately to investigate. Machanga followed shortly afterwards and they both triggered the audio.

Machanga left quite quickly, but Janu stayed to test the radio some more.

The data logger didn't work (boo) but there was some night footage of the elephants interacting with the buttons again at about 2am.

Copper plate after elephant use – lots of slime

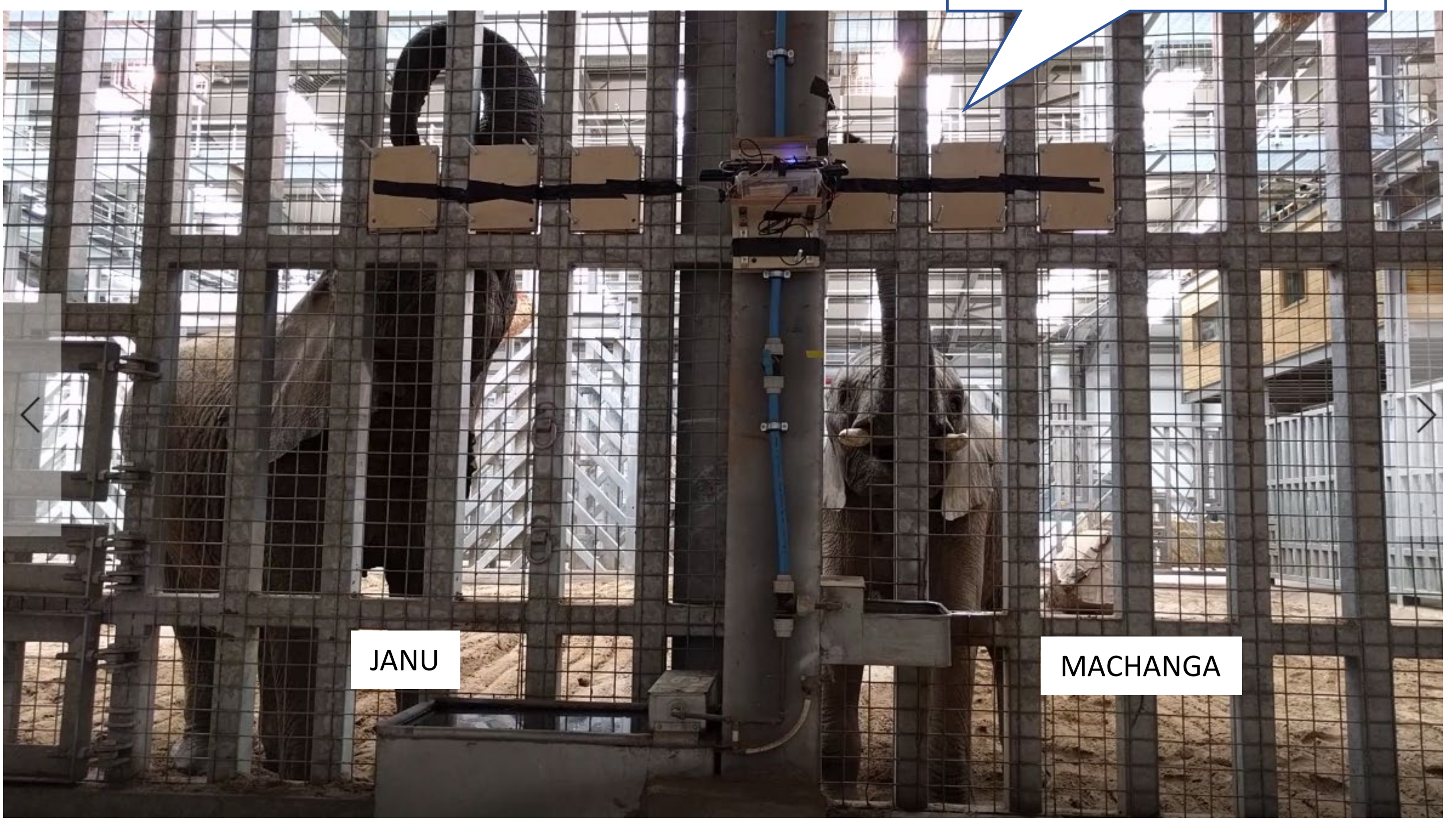
Testing the radio

Janu plays by himself

MEDIA LINKS

- Janu and Machanga play with radio https://vimeo.com/406330458

The elephant keeper at Noah's Ark explained that the young bulls might need to be separated - we created 2 identical systems mounted on either side of a temporary barrier so they could each have the opportunity to play.



Input: Digital

MAY 2016: RADIO / CAP SENSOR

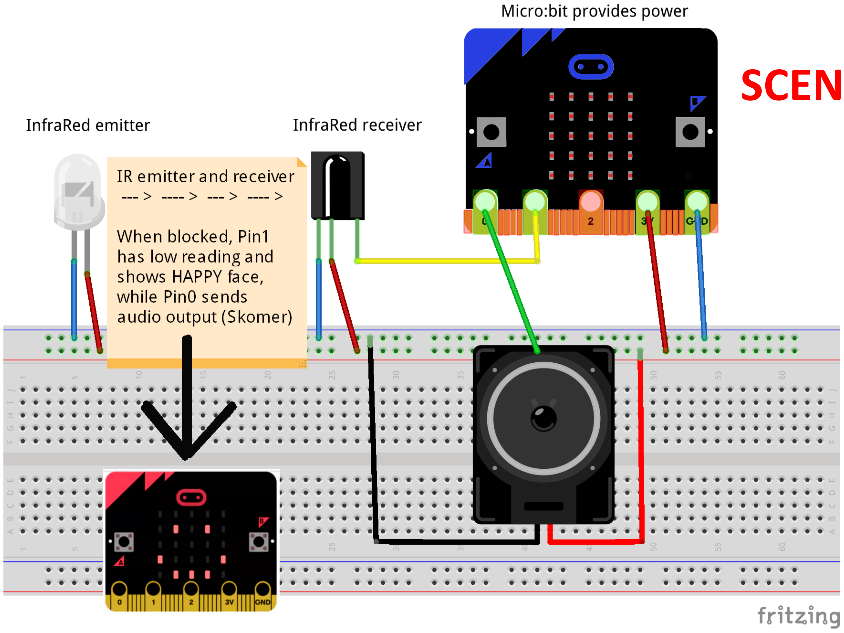
		INSIGHTS				
DEVICE	Date	Testing - tech - sensors	Output	Elephants - materials - dimensions	Location	People
RADIO	Jun-16	**Why did we try capacitance sensing again?** Try and learn from mistakes! Issues with environment. Do some test with alternative sensor technology – beam-break button.	Acoustic	**Some elephants like being able to trigger interesting sounds.** Animals are individuals – so if system doesn't work with one, it might work with another. Important to do multiple trials.	**Radio placed above eye-line but as soon as elephants moved further away from wall they spotted it and came to investigate.** Validation of keeping new devices visible. Indicates curiosity not fear.	**Complex system for keepers to maintain – needed re-setting.** KIS – it's not only for the designer, but also for the community – lots of stake-holders, time critical.
		Batteries Always going to be an issue in the field – timed tests only? But keepers willing to allow mains supply in future.		**Interplay between Janu and Machanga and the radio** hard to interpret – dominance or interest?	**Great to have 24-hour footage** Surveillance is useful for maintaining records for a scientific (quantitative) study. A benefit of captive situation?	**Flexibility and willingness of keepers critical.** This experiment couldn't have been carried out without support from the keepers at Noah's Ark, who tried very hard to maintain the radio system after we left. In fact, it was too complex and error-prone for anyone to use effectively – see point below.
		Too complicated to share. The radio tried to accomplish too many things at once, and failed. We were not able to log data effectively, nor keep system going due to batteries running out; the sensors also failed.		**Young males didn't destroy.** Contrary to (some) zoo-keeper opinions, the elephants didn't rush to trash the system, even when it stopped working properly. Wooden boxes either sufficiently robust or elephant temperament calmer than expected. Thumbs up for construction and materials.		**Teamwork can be tricky.** Ashley and I were working to different schedules which meant there was a lot of pressure to offer a technical solution within a limited time frame. Suggest postpone working with others until after initial technical issues have been ironed out so that challenges can be met in timely fashion.
		Good to leave and watch, no training! Finally using a different methodology for testing. Let's keep with this.				**Need for technical support.** It would have been great to have had a technical team as well as animal experts involved in the project. I will try to reach out to colleagues who have appropriate skills.
						Maintain good relations with keepers to obtain their expert opinions.
CONCLUDE		BEAM-BREAK		INDIVIDUALITY	FENCE + VISIBLE	KIS / no training

During early discussions with EWG and later discussions with colleagues at London Zoo (Whipsnade), the simplicity of **IR beam break** sensors was mentioned. Following some challenging situations where a device working in lab failed to work in the field (e.g. solenoid valve, capacitance sensor), we decided to test this option … but not with an elephant – firstly with a dog.

Other take-aways from the radio were the need to keep each test as simple as possible (for elephants AND keepers) so that we could leave system in place and rely on keepers to maintain it. For this reason we decided to experiment with using Micro:bit (microcontroller) instead of Arduino. Micro:bit is designed to be very user-friendly (aimed at teenagers) and might therefore be less intimidating tech for people who were not used to electronics.

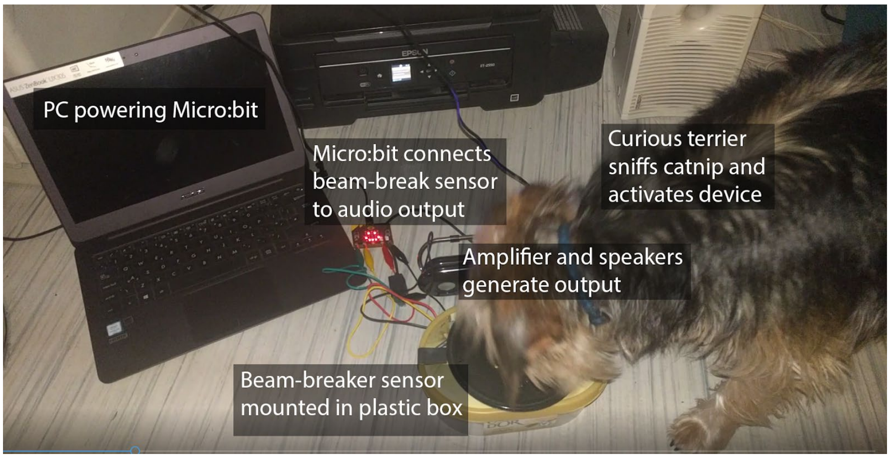
Additionally we needed to keep in mind that elephants are individuals – this could be particularly tricky with acoustic outputs which are pervasive over a wide area. "I don't like jazz." "Well I don't like hiphop." "And I just want some peace and quiet."

MAY 2016:
SCENT / IR BEAM BREAK

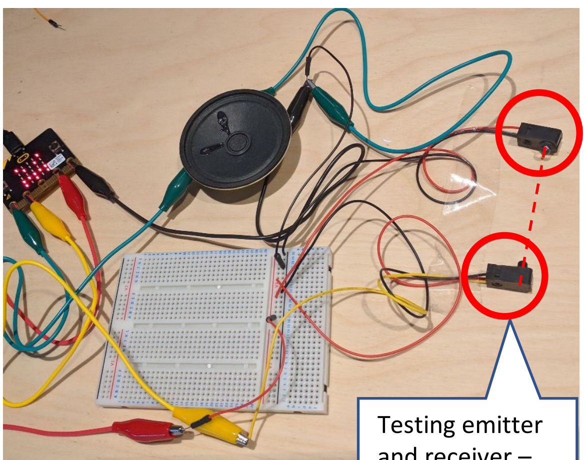


BLOG POST: 3 Aug 2017
For this tech test, I set up a simple beam-breaker sensor that activates an acoustic output. It uses 5mm IR Break Beam Sensor from Adafruit, connected to BBC Micro:bit (see Fritzing sketch below).

The sensor comes in 2 parts - an emitter and a receiver - I mounted them in a plastic bowl that sits in an icecream container. When something (eg. dog nose) passes between emitter and receiver, the beam is broken and the microcontroller captures this change as an input, then triggers an acoustic output which is amplified through speakers.



MEDIA LINKS
- Skomer testing beambreak https://vimeo.com/406352770



Testing emitter and receiver – must be aligned

Skomer wonders if any biscuits are involved

3/8/2017
In this case, the output was programmed in Python so I could use the speech library and offer robotic doggy feedback ("SKOWMERR.."). I used some catnip behind the sensor to encourage noses to investigate and in principle it works... Skomer found it easy to use but was not particularly interested in the output. She's a 2 year old Yorkie/Jack Russell mix, very sociable, loves ball games and other interactive playful experiences - triggering weird noises not her thing (she's quite capable of generating her own).

MAY 2016: SCENT / IR BEAM BREAK

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
START		**BEAM-BREAK**		**INDIVIDUALITY**	**FENCE + VISIBLE**	**KIS / no training**
BEAM-BREAK	Aug-17	**In principle this works well.** This was rough and ready test of sensor tech with an available animal – useful guide for future crafting as there are some similarities between dogs and elephants (what are they?)	Acoustic	**Easy to construct – for dogs.** Flimsy plastic prototype but we will need wooden frame construction for elephant – positioning sensors will be critical.		
		Micro:bit could be alternative to Arduino? It's cheap and simple to use with very accessible programming interface.		**Catnip holds little interest for dogs.** Well duh. But not irrelevant for working with elephants – just demonstrates that the quality of **olfactory stimulation** would be critical.		
CONCLUDE		**TECH TESTS**		**OLFACTORY**		

Beam break works fine and could be repurposed in an elephant device. We established there's a need to perhaps do more tech tests before trying devices in the field, and that it would be reasonable to divide testing phases into interface-only (for aesthetic interest) and technology-enabled (for functionality).

Using catnip to attract the dog (not particularly successful) raised the issue of olfactory stimulation again, but we will continue to experiment with different **tactile** surfaces, focusing on non-olfactory aesthetic qualities. Everything has a variety of smells in any case, most of which we are unable to discern.

My dog was inclined to investigate a novel object, initially with her nose. She demonstrated curiosity. In this respect, her behaviour resembles Valli's behaviour. As Valli has grown up at Skanda Vale and is cared for using full-contact from her keepers, she seems very domesticated. I particularly noticed this when on a walk with Brother Peter and Valli, when her playful demeanour and response to his talking reminded me of my walks with Skomer, but at a much slower pace.

DISSEMINATION

2016 French F, Mancini C, Sharp H. Exploring methods for interaction design with animals: a case study with Valli. Paper at *ACI 2016*. DOI: http://dx.doi.org/10.1145/2995257.2995394

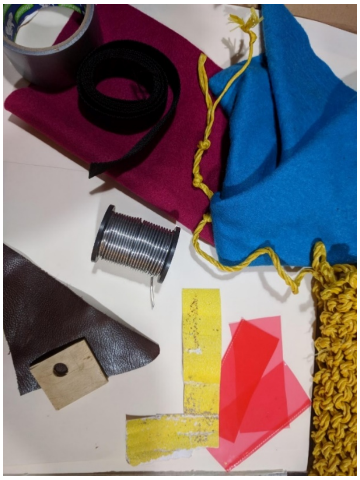
2017 French F, Mancini C, Sharp H. High tech cognitive and acoustic enrichment for captive elephants. *Journal of Neuroscience Methods* Volume 300, 15 April 2018, Pages 173-183. https://doi.org/10.1016/j.jneumeth.2017.09.009

2017 French F, Mancini H, Sharp H. Exploring Research through Design in Animal-Computer Interaction. Paper at *ACI 2017* (November 2017). DOI: 10.1145/3152130.3152147

Input: Digital

AUGUST 2018: TACTILE / CAPACITANCE

BLOG POST: 5 August 2018
Everyone has gone to Ireland, so I have a bit of time for making.



I want 3 identical tactile controls so I can see if Valli actually prefers to explore the one without any acoustic feedback. I've chosen a range of materials with different tactile qualities that might be interesting for a trunk tip to explore - and made myself a handy template trunk tip to remind me of the dimensions of an elephant when I'm constructing stuff.

The bases are solid plywood, so we can bolt through the fence to secure as usual. Then there's a layer of conductive material with a metal (iron) angle bolted across the face and protruding out the back. We're going to use the entire face as a large capacitance sensor, which requires one wire attached to the angle (on elephant-free side of fence) back to microcontroller to provide a reading.

The other layers are glued on top of the conductive material, gradually building up a non-conductive surface through which the sensor will obtain readings. Thus, at one end the reading is high, and at the other, it is low. There should be four clearly different readings, depending on where Valli is touching the sensor, and these will be mapped to different outputs.

The materials used will have olfactory as well as tactile properties (eg. strip of leather, old rope) and no doubt everything will stink of glue to an elephant's super-sensitive appendage. But I have long ago given up trying to tease apart the different sensory qualities of manufactured objects - at this stage I'm just using intuition and imagination, crafting what I can and then hoping to gain insight when I see Valli interact with the devices.

Smooth blue material + yellow sandpaper

Yellow rope

Red plastic

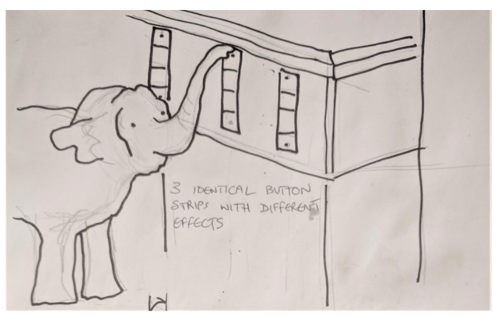
Black braid

Leather diagonal strap across white paper

Wire bar

Rope twist on smooth conductive fabric

Metal bolt on wood



Elephants are partially colour blind, but like dogs, can distinguish between blue and yellow.

OCTOBER 2018: TACTILE / CAPACITANCE

3 identical multi-buttons

MEDIA LINKS
- Valli plays with buttons (no audio on CCTV) https://vimeo.com/406664392

BLOG POST: 14 Oct 2018
Trip to Skanda Vale this weekend, armed with a range of devices for Valli to try out.

We hung some rope from a cross-beam and monitored how often she interacted with it; installed the 3 identical tactile interfaces that were supposed to trigger different sound effects.

The team at Skanda now have some sophisticated monitoring equipment, with cameras in several positions inside and outside the elephant barn. It's possible to view recordings from all the cameras overnight and check whether and how often and how Valli interacts with objects in her surroundings.

Stills from monitor camera footage show Valli investigating each button. Yet again we had issues with capacitance sensors (why did I try that again?) so unable to conduct the original experiment.

Input: Digital

OCTOBER 2018: TACTILE / CAPACITANCE

DEVICE	Date	INSIGHTS Testing - tech - sensors	Output	Elephants - materials - dimensions	Location	People
START		TECH TESTS		OLFACTORY		
TACTILE	Aug-18	**Failing capacitance again?** What was I thinking about? For goodness sake use a different sensor. Deploy something that has history of working and focus on output.	NONE	**Valli explores surfaces.** Validation of multi-textured interfaces – consideration of tactile properties… **especially** things that move		**Continued support from Skanda Vale community.** The Brother who helped mount the buttons asked if he could take one as a keepsake because he was intrigued by design. Take some paintings next time as a gift?
		Trying to do too many things at once. Stick to one parameter.		Or rather HOW an elephant would control sound - ANALOGUE		
		Development time v. elephant time. It took a long time to create these buttons; working with different materials to construct identical designs and testing capacitance through layers. Too much time invested for such an early prototype. Suggest repurpose some old button frames with different tech.			 A YEAR LATER	
		Convergence of input and output to create a viable system. Enough interface design for DIGITAL (on/off) buttons – this is now about proper MAPPING of output to input so that we can see if an elephant chooses to trigger the output. Consider a **haptic button?**				
CONCLUDE		CONTROL ONE PARAMETER		MOVING CONTROL		

Although the stripy buttons were interesting for the elephant to touch, we were trying to achieve too much at once – a mistake we made earlier. In any future tests, we'll aim to just control one output. This would be easier for an elephant to comprehend and also easier for us to obtain meaningful results from the experiment.

While considering the properties of objects that have interest for an elephant, our thoughts returned to moving objects. Previously, these seemed too ambitious to manufacture so they would be sufficiently robust, yet the advantages are many. A moving object has a strong affordance, once the animal has understood that it moves – there are clearly different positions it can be in, which offers the animal a choice and a clear sense of being able to control something. Moreover, if the movement can be picked up by a sensor, the device offers an opportunity for providing a graduated controlling mechanism – an **analogue input**.

We had attempted to construct a slider potentiometer earlier in the year, documented in the next section, which deals with all our analogue tests.

Feb 2020: NAUGHTY ELEPHANTS AGAIN
After a year, when I revisited the elephant shed, the stripey multi-buttons had been stripped bare by the elephants (now a pair – Valli and Lakshmi).

Brother Stefan told me that when Lakshmi had discovered the button (she's blind), she systematically tore off all the features. I hope it was fun!

Input: Analogue

RATIONALE & EARLY CONCEPTS

2014: Early interest in **analogue input devices**. Spend a lot of time conceptualising what these might look like and how they would work, as well as considering what could be controlled.

Rationale
The value of analogue input is that it offers a range of choices, enabling us to understand, for example, how much of something is desirable for the animal, rather than trying to guess. It enables her to give us some valuable feedback on her preferences – not just black or white, but all shades of elephant in between.

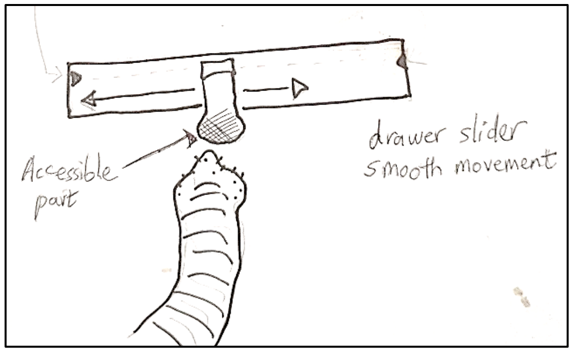
Sliders seemed to indicate a scale that is intuitively easier to comprehend than a knob – for a human.

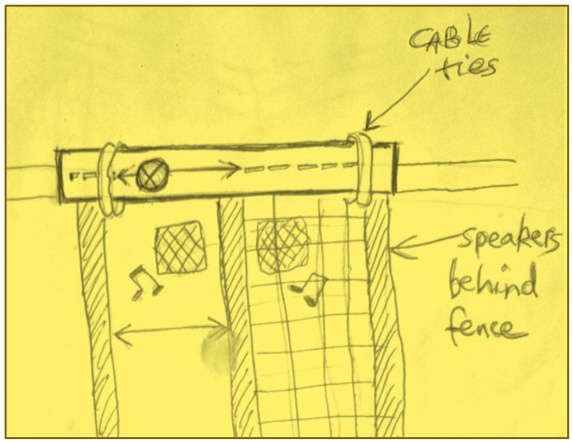
But what actions would an elephant perform naturally in the wild?

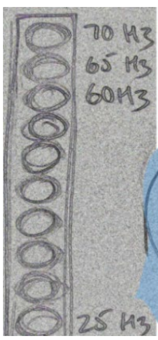
We have seen that elephants PULL down tree branches…

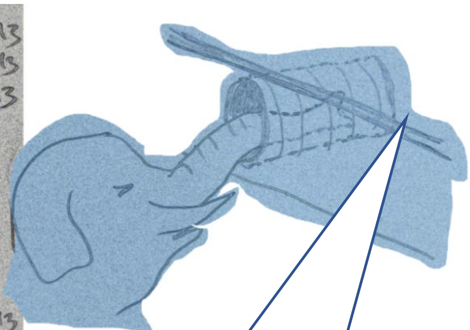
Scaled up to elephant size, this knob would be about 700mm diameter – how much would it weigh?

In fact **trunk tip** can control much smaller object – around 100mm.



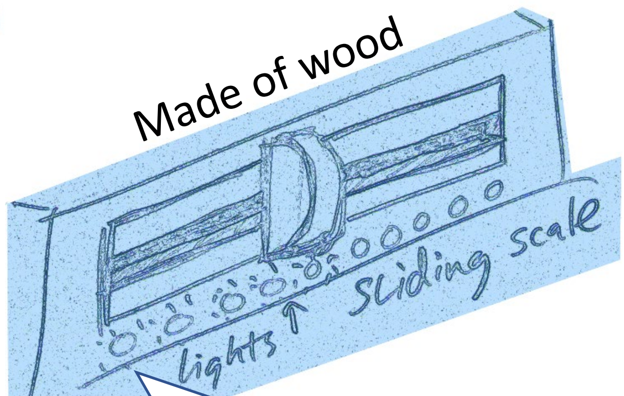






EWG suggested that elephants like investigating small gaps (such as pipes) with their trunks; would require hidden sensor. Measure distance from end in real time gives a graduating scale; the further down the pipe, the greater the effect – eg. volume, pitch, light.

But she would need to keep trunk in position.



Lights here are indicators that something is happening as the slider is moved horizontally – also provide feedback to humans

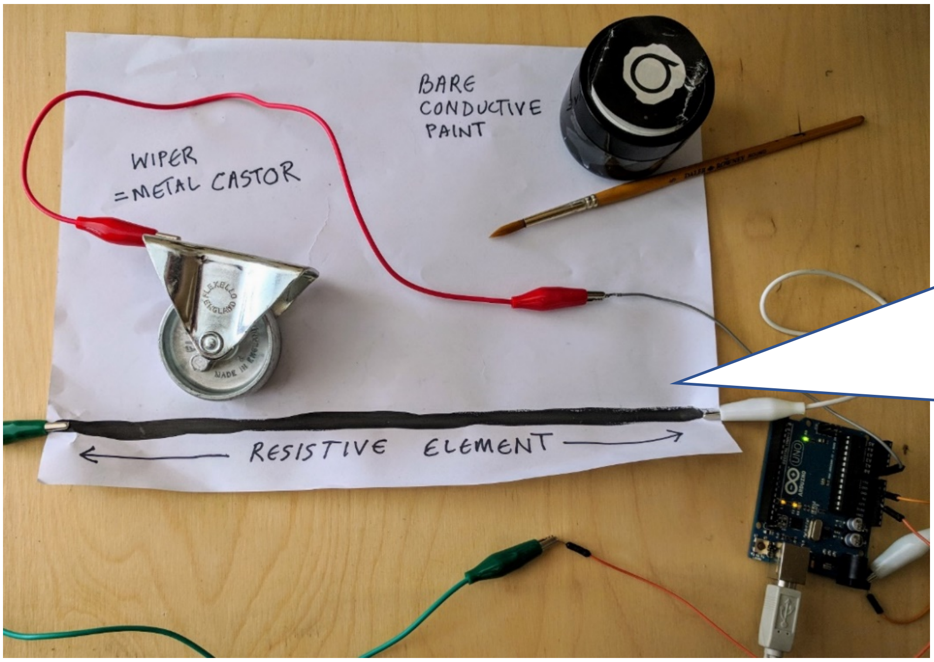
MAY 2018:
SLIDER 1: CONDUCTIVE PAINT

BLOG POST: 12 May 2018
This post is about designing the physical and electronic aspects of giant slider control mechanism. A subsequent post will explore the quality of the acoustic output.

I'd like Valli to be able to control an aspect of the acoustic system we offer her. I've considered a theramin-style device, but the conceptual mapping between proximity and output seems a bit vague and potentially hard to comprehend - after all, it's difficult for a human to master the controls.

Other possibilities might be a rotating knob or a lever that could be pulled. While I believe she could learn to use a knob, turning things is not an obvious aspect of an elephant's usual repertoire of movements (except twisting leaves off a branch, for example). Pulling (which is very natural behaviour) raises manufacturing challenges - how to create something sufficiently robust?

Humans use sliders to control acoustics in synthesiser hardware, and the mapping between wiper position and output seems intuitive to us, so I thought I'd try and design a massive version of a slider potentiometer.



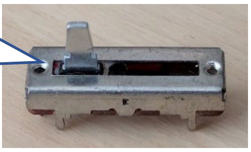
Testing conductive paint as resistive element for a slider potentiometer.

The castor is iron. As the wheel moves along the paint strip (which is charged with 3V from Arduino) it sends back a changing voltage depending on length of resistive paint

12/5/18
Slider pots have a resistive element, which can be coiled resistance wire, carbon film, carbon-impregnated non-conductive material, foil etc. A wiper moves freely along the element, sending different resistances back to the microcontroller (Arduino analogue pin). I have found that Bare Conductive [electric paint] is easy to use and provides a great element that can be sized to suit.

CHALLENGES – can we use resistive paint on wood as a resistive element? How could the elephant roll the wheel, which has to maintain contact with the strip at all times?

Real slider pot is about 30mm

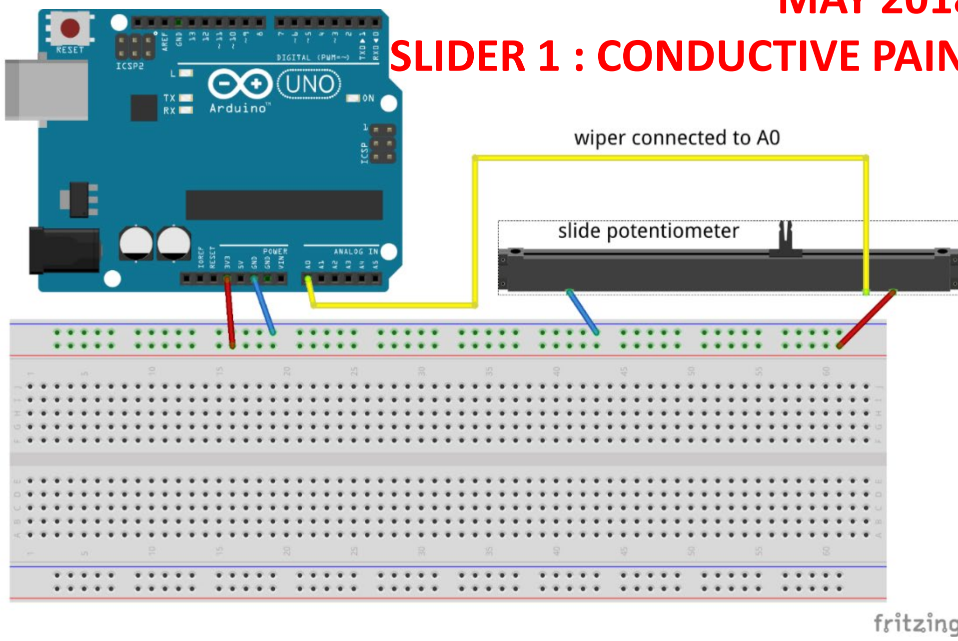


MAY 2018:

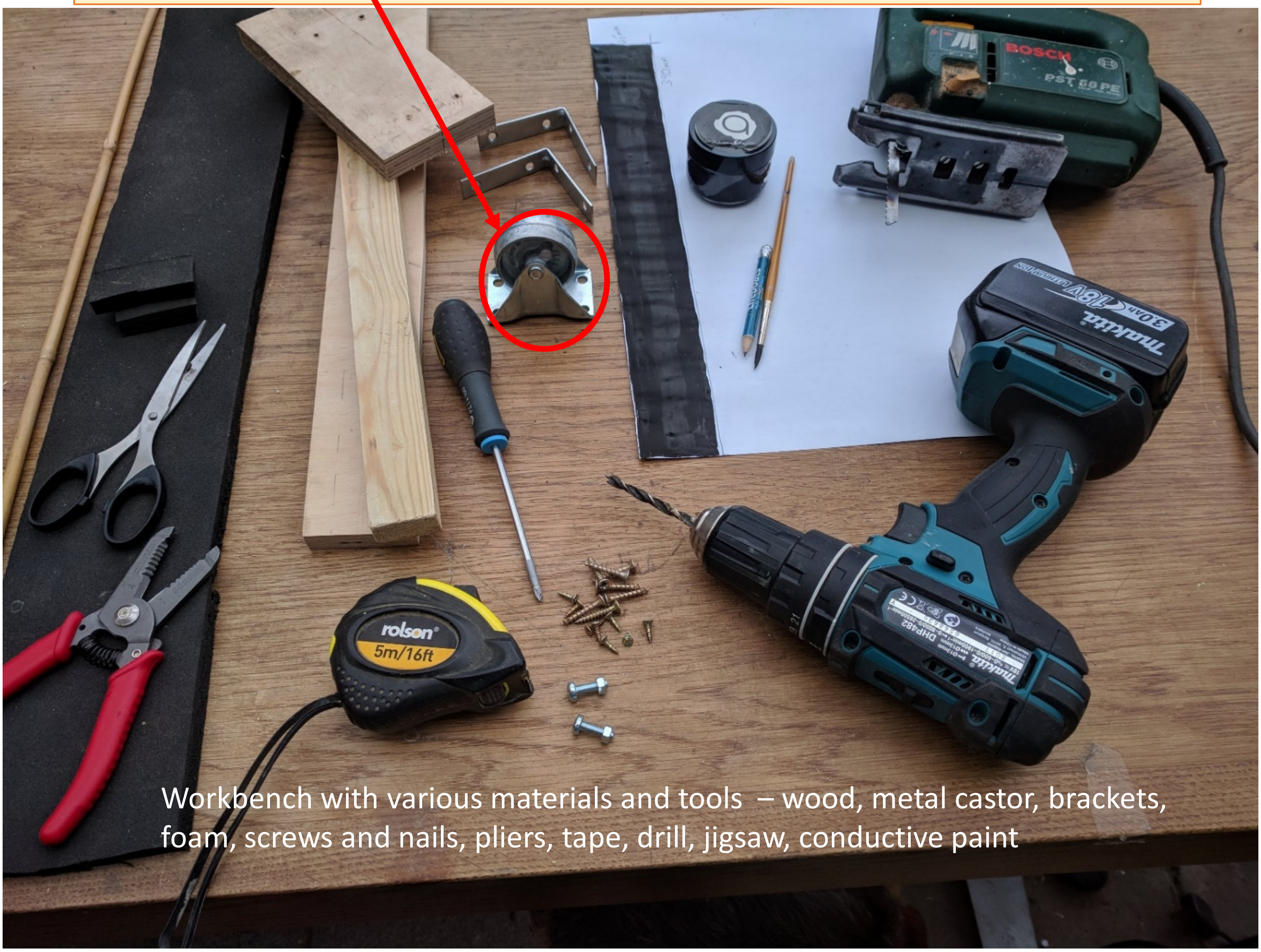
SLIDER 1 : CONDUCTIVE PAINT

Serial output to Processing on PC

Simple connection to Arduino analogue input

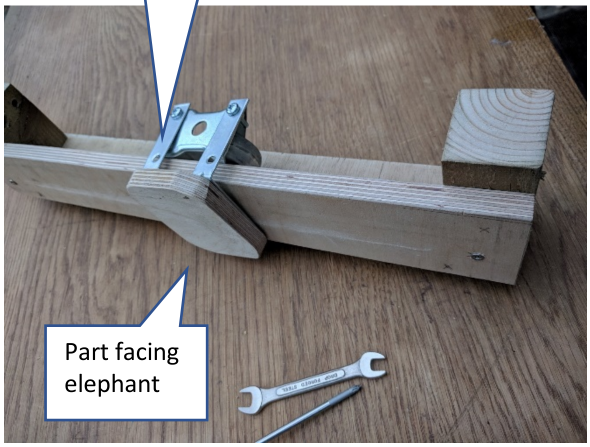


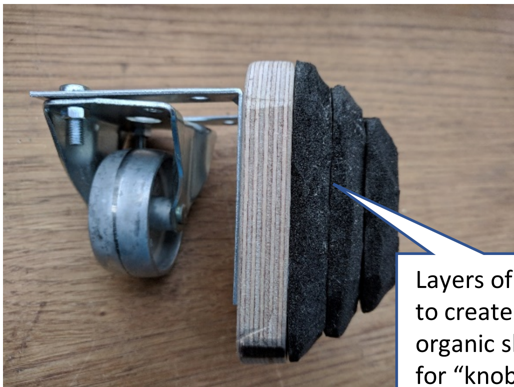
12/5/18
The wiper part became an interesting problem, as it needed to be sufficiently large and robust to be manipulated by an elephant, while maintaining contact with the element. I investigated the potential for repurposing old drawer sliders, which have a lovely smooth mechanism, but the runners are plastic, so no contact is made with fixed section, and they are heavy. A metal castor (see photograph) seemed easier to develop into a controller and worked well with the painted strip.

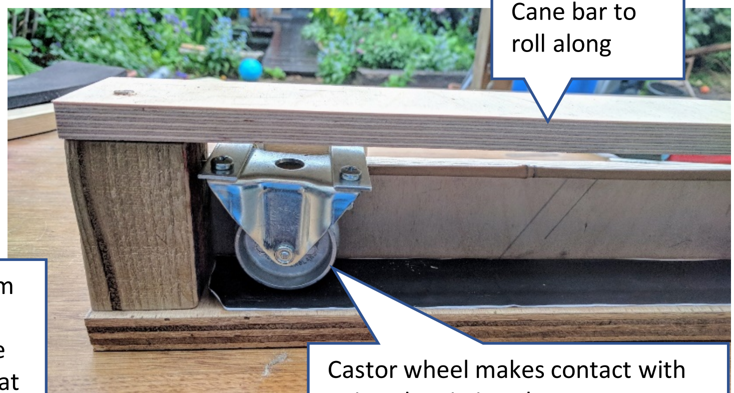


Workbench with various materials and tools – wood, metal castor, brackets, foam, screws and nails, pliers, tape, drill, jigsaw, conductive paint

MAY 2018:
SLIDER 1 : CONDUCTIVE PAINT







12/5/18
This is the current state of the device, seen from both sides. Small brackets, bolted to the top of the castor, pass over a wooden frame and hold a rounded "handle" that can be used to slide the wheel across the resistive element (electric paint). Aesthetics not yet finished.

CHALLENGES – resistance readings are poor because the contact between wheel and plate is not consistent - there needs to be some pressure to keep the wheel down and elephant could easily lift it or pull it off.

Input: Analogue

MAY 2018:
SLIDER 1 : CONDUCTIVE PAINT

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
START		**SLIDER**		**MOVEMENT**	**AIM FOR A BALCONY DEVICE**	
SLIDER 1 - PAINT POTENTIO-METER	May-18	**Sensor challenges.** Potentiometer measures change in resistance but requires consistent contact between resistive element and slider - wheel has no pressure.	NONE	**Size.** Too small for elephant - use a life-sized template when working remotely.		**Feedback.** Visual feedback, such as lights, would benefit keepers and researchers as well as elephant users.
		Difficult to slide. Wheel is not smooth running - try conductive fabric over foam to provide springy pressure?		Humans typically use sliders and knobs to control audio output, and a slider has an obvious visual affordance - position along a line/scale. Could an elephant understand the alignment and how it applies to the output of the system?		
		Control is critical again. Fluctuating readings with home-made resistance sensor would give strange output.				
CONCLUDE		**CONDUCTIVE FABRIC RESISTANCE**		**TEMPLATE**		

The slider was made from a bunch of repurposed objects lying around in the workshop – old castor, bits of wood, metal fittings…. However, it gradually became obvious that a proper sliding feature would need to be properly manufactured. We had one last attempt this month, using **conductive fabric** over a length of foam (because it would be springy).

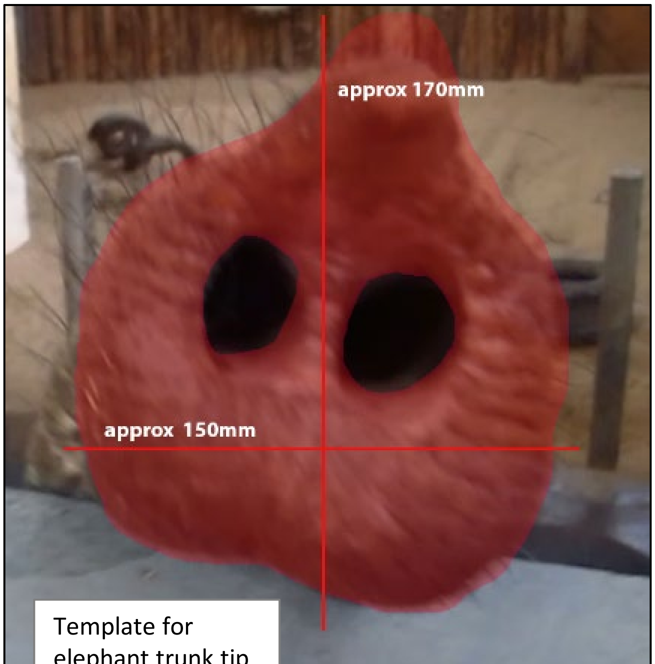
Another aspect was the scale of the device. It is always difficult to remember how big an elephant is when you are several hundred miles from your favourite elephant. I kept thinking of my arm as a stand-in trunk, whereas in fact my arm and my fingers are tiny in comparison with an elephant's appendage. It became useful to be able to refer to a life-size model when we were building devices for elephants…

Workshop union rep watches proceedings

MAY 2018:
SLIDER 2: CONDUCTIVE FABRIC

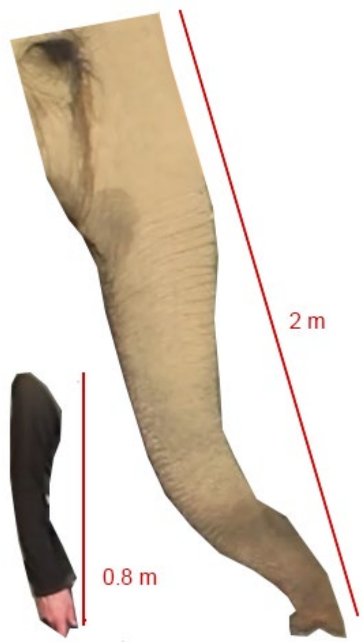
The next stage was to use conductive fabric instead of paint, and to cover a foam bar so that there would be a slight pressure upwards on the castor at all times.

CHALLENGES
Similar problems with scale and getting consistent readings.
Is it big enough? Robust enough?
Limited fixings for attaching to the balcony metal grille



Template for elephant trunk tip showing scale

HANDS, ARMS and TRUNKS



MAY 2018:
SLIDER 2 : CONDUCTIVE FABRIC

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
START		**CONDUCTIVE FABRIC RESISTANCE**		**TEMPLATE**		
SLIDER 2 - TEXTILE POTENTIO-METER	May-18	**Potential lab v. field problems.** Good readings, but difficult to house. Try a pre-made slider…	NONE	**Appreciating trunk dimensions.** Template is good		**TEAMWORK.** Not possible for me to make a larger mechanism by myself, so contact in-house team.
				Craft with fabric is interesting but not robust enough. Find a metal / wood solution.		
CONCLUDE		**DRAWER SLIDER**		**LARGE WOODEN HOUSING?**		**HELP FROM CASSWORKS for CONSTRUCTION**

The fabric slider worked, but seemed unlikely to be able to withstand an elephant's attentions. The slider could also be a bit tricky to push and we wanted something that glided easily – like a drawer. So instead of trying to make a giant potentiometer, we turned our attention to different kinds of analogue sensors. There were ones that we had used successfully before, like infra-sonic sensors, and ones to avoid, like capacitance sensors.

However, although the concept of a drawer slider seemed good, we were not yet in a position to manufacture a suitable housing. Fortunately, Londonmet has a well-equipped workshop that is part of the CASS School of Art, Architecture and Design. We were able to arrange some support after the summer break – discussed in the next Slider episode. But in the meantime, we revisited our elephant tester with some other ideas.

Using **ropes** had been a feature of several of our early ideas and was worth exploring in the field…

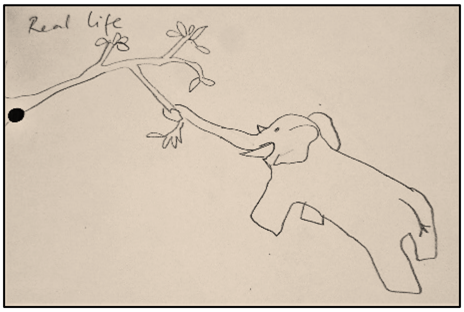
Input: Analogue

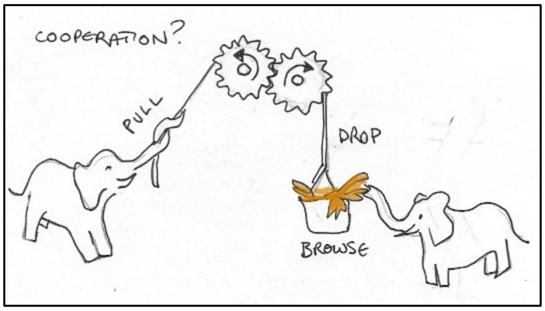
OCTOBER 2018: ROPES

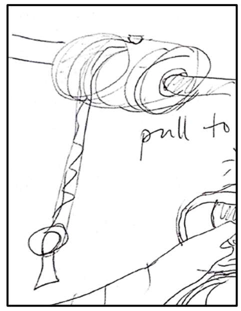
African elephants tear down tree in Namibia, 2015

Asian elephant Valli foraging in Welsh countryside, 2016

All species of elephant use their trunks to pull branches – for food, for fun, because they can… We could offer ropes (and pulleys) because they would invoke a natural reaction. There is a clear analogue quality to this behaviour relating to how much FORCE is exerted to pull the object – and in which DIRECTION.





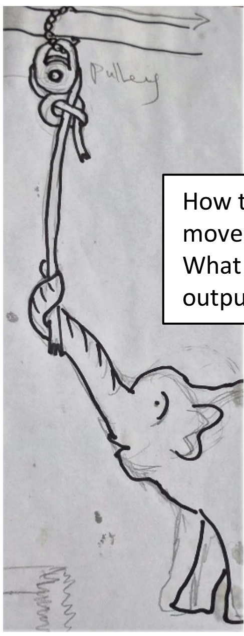


BLOG POST: 14 Oct 2018
Trip to Skanda Vale this weekend, armed with a range of devices for Valli to try out.

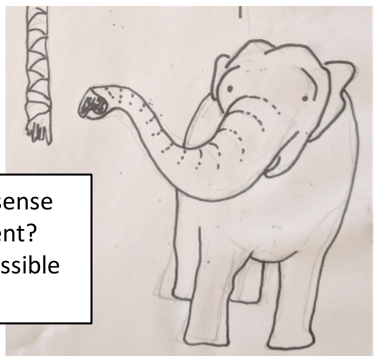
We hung some rope from a cross-beam and monitored how often she interacted with it …

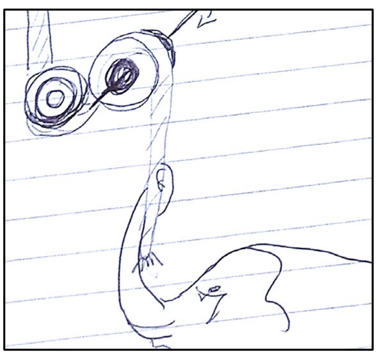
I'm explaining to one of the Brothers where I'd like to hang rope…

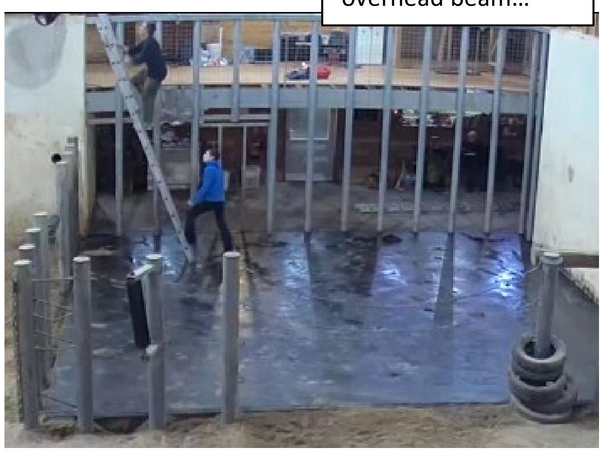
Here's Brother Alistair heading up to attach the rope (old barge rope) to an overhead beam…



How to sense movement? What possible output?

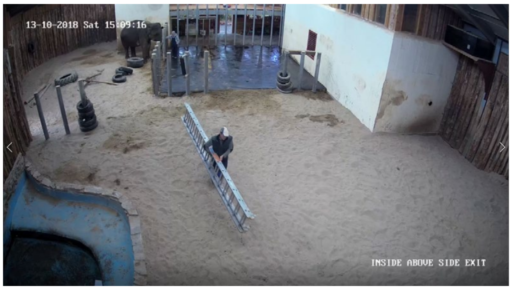






OCTOBER 2018: ROPES

TESTING ROPES

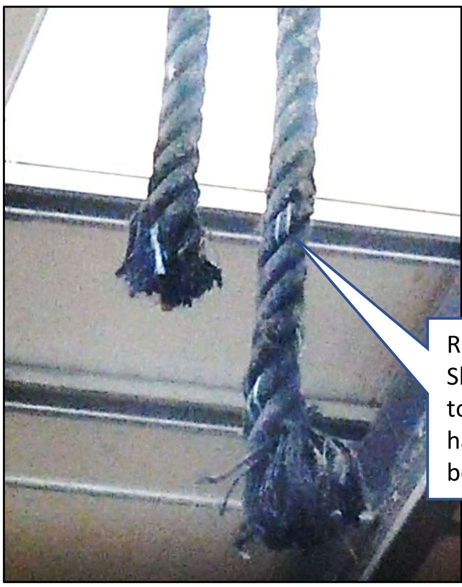


14/10/2018
… The team at Skanda now have some sophisticated monitoring equipment, with cameras in several positions inside and outside the elephant barn. It's possible to view recordings from all the cameras overnight and check whether and how often and how Valli interacts with objects in her surroundings.

I spent a few hours checking and downloading footage (by viewing at high speed), finding more instances of playful behaviour than first impressions might have given us.

Checking camera angle

Importance of teamwork



Ropes installed in Skanda Vale in 2018 to gauge interest – hanging from roof beam.

Screenshots from videos supplied by Brother Peter at Skanda Vale.

Lakshmi shows more interest than Valli in spending her time playing with the rope – individual preferences.

MEDIA LINKS

- Lakshmi with rope
  https://vimeo.com/406648279
  https://vimeo.com/406648146

OCTOBER 2018: ROPES

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
START		**CONTROL ONE PARAMETER**		**MOVING CONTROL**		
ROPES	Oct-18	**Analogue measurements.** Discussions with EWG Lisa Yon revealed that using bungees has been suggested as a way of keeping track of HOW MUCH the elephant pulls the rope – theoretically this could be mapped to an output so that the act of pulling offered a graduated control.	NONE	**Mental models.** Interface elements that mimic an elephant's natural world have obvious affordances for elephants – thus ropes will automatically be tugged without the animal having to learn what to do.	**Although very elephant - friendly**, attaching sensor to top of rope and monitoring it would be time-intensive.	Great support from keepers, helping to hoist ropes to beam. However, it's difficult and location-dependent so not easy to scale up.
		Future directions. Although ropes look promising, not sure how to capture movement data, so we will investigate potential for using sliders as analogue inputs.		**Movement.** Swinging rope – more engaging than a static object – gives a sense of control. Any moving part holds promise for being interesting, as well as giving rise to challenges, such as durability, safety and integration with tech.		
CONCLUDE		**SLIDER**		**MOVEMENT**	**AIM FOR A BALCONY DEVICE**	

NOTES
A year later, after Lakshmi has discovered the rope, it is reduced to shreds because she has torn apart little pieces and eaten or discarded them.

We're slowly building up a picture of Valli's aesthetic preferences – she likes to touch new objects and trace their contours; she seems interested in textured surfaces and vibration; anything novel attracts her attention; she likes to pull things apart – in fact, destruction is a clear motivation for her. She is capable of retrieving and tearing very small items, yet she has great strength. It seems very likely that she would engage with a moving object more than a static object because she would have greater control and ownership of it.

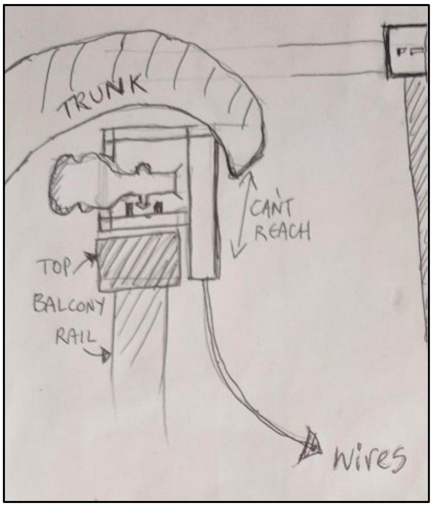
The challenge is to create an interface that allows **movement** yet remains indestructible, while simultaneously allowing us to capture the input data using sensors so we can map it to a suitable output (**analogue**). So let's SCALE UP the slider concept and do it properly!

The **drawer slider** developed over about a year, and a working version was finally tested at Skanda Vale in early 2020…

Input: Analogue

MAY 2019:

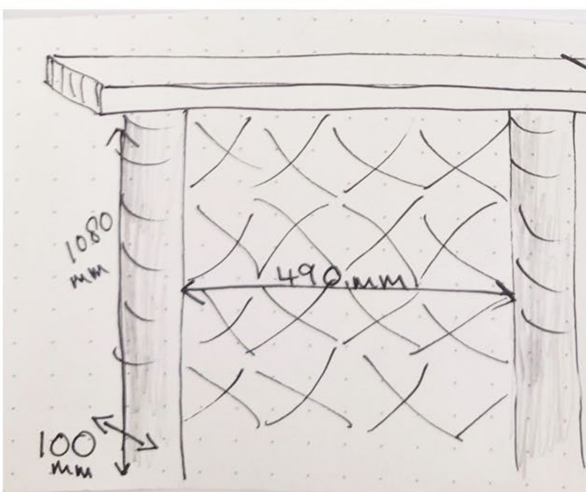
SLIDER 3: DRAWER / INFRA-SONIC

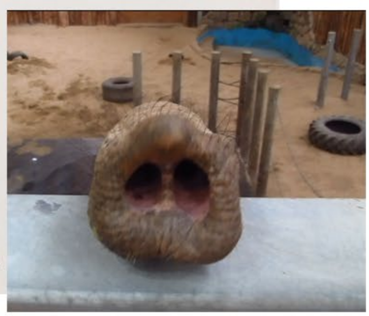


We want this to be bolted to the balcony – if it runs along rail at top, the length is flexible; if it's fitted between metal uprights (like other interfaces) there's a 490mm limit, which doesn't give much room for sliding. It has to be horizontal so it doesn't keep slipping down to the bottom.

Valli can reach to the top and stretch over a little bit – enough to say hello and grab any loose wires…

Balcony rail dimensions

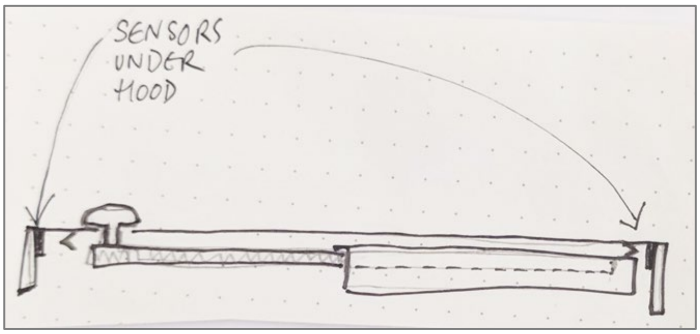




MAY 2019:
SLIDER 3 : DRAWER / INFRA-SONIC

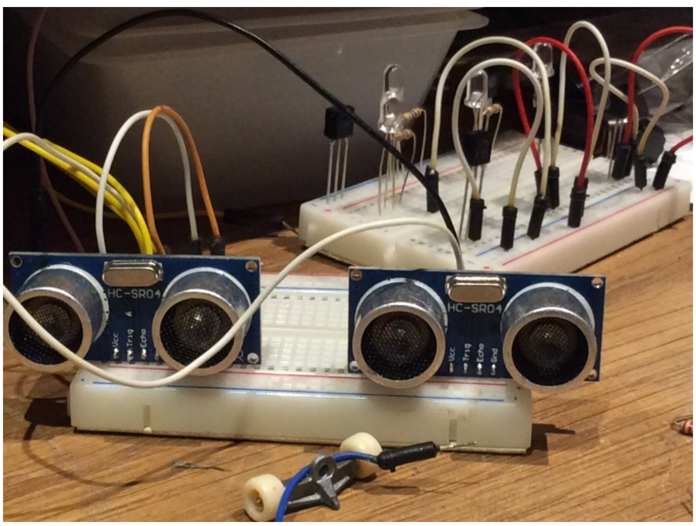
Resistance sensing proving too tricky, so since we have useful moving parts in the form of ready-made sliders repurposed from old drawers, let's try using proximity sensing with an ultra-sonic device.

Range of drawer sliders



As the slider moves, a pair of ultra-sonic sensors mounted at either end measure distances

I did some quick tests with cheap HC-SR04 sensors in 2016, and they are very accurate with a range of around 20 – 200mm



BLOGPOST: 4 April 2016
I've been experimenting with different kinds of sensors - ultra-sonic HC-SR04 (pictured), PIRs, and beam-breaking IR pulses at 38kH. They all work fine independently.

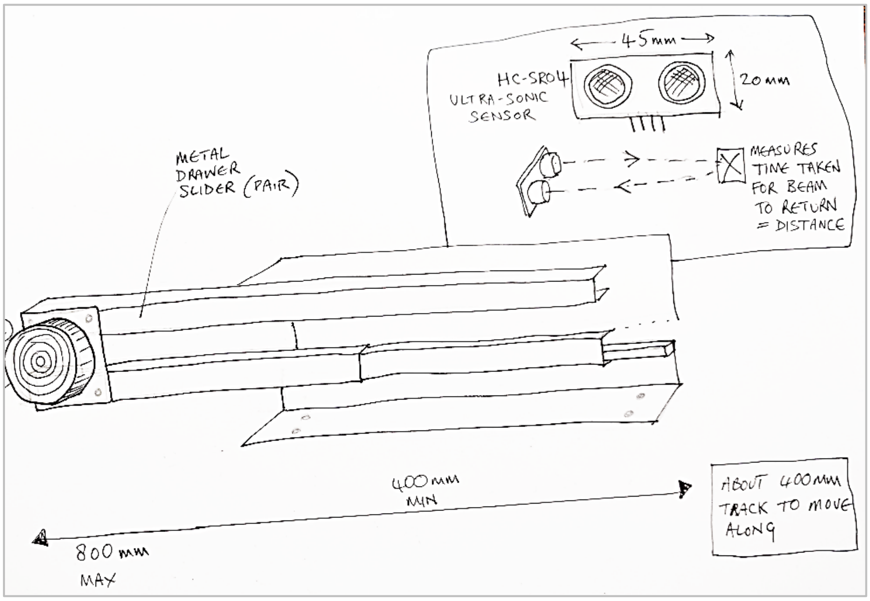
And I've built a wave shield for Arduino, which plays .wavs at specific format from a SD card. That works. And the data logger seems to be working, although I haven't written any data to it yet.

The current problem is that Arduino can't simultaneously ping a lot of beam breakers, far less do that and also log data to one SD card whilst playing .wavs from another... a bit annoying.

So the data-logger needs to be controlled by an ultra-sonic sensor that just uses one pin to give an accurate proximity reading, and I might hack a cheap mp3 player to provide the audio output instead of using the wave shield.

Constructing this device feels as if it might be challenging with the equipment I have to hand. It's going to be bigger than any other prototype and require some refinements to make it useable and safe. I decide to design and discuss with CASS wood and metalworking expert Chris Hosegood.

MAY 2019:
SLIDER 3 : DRAWER / INFRA-SONIC

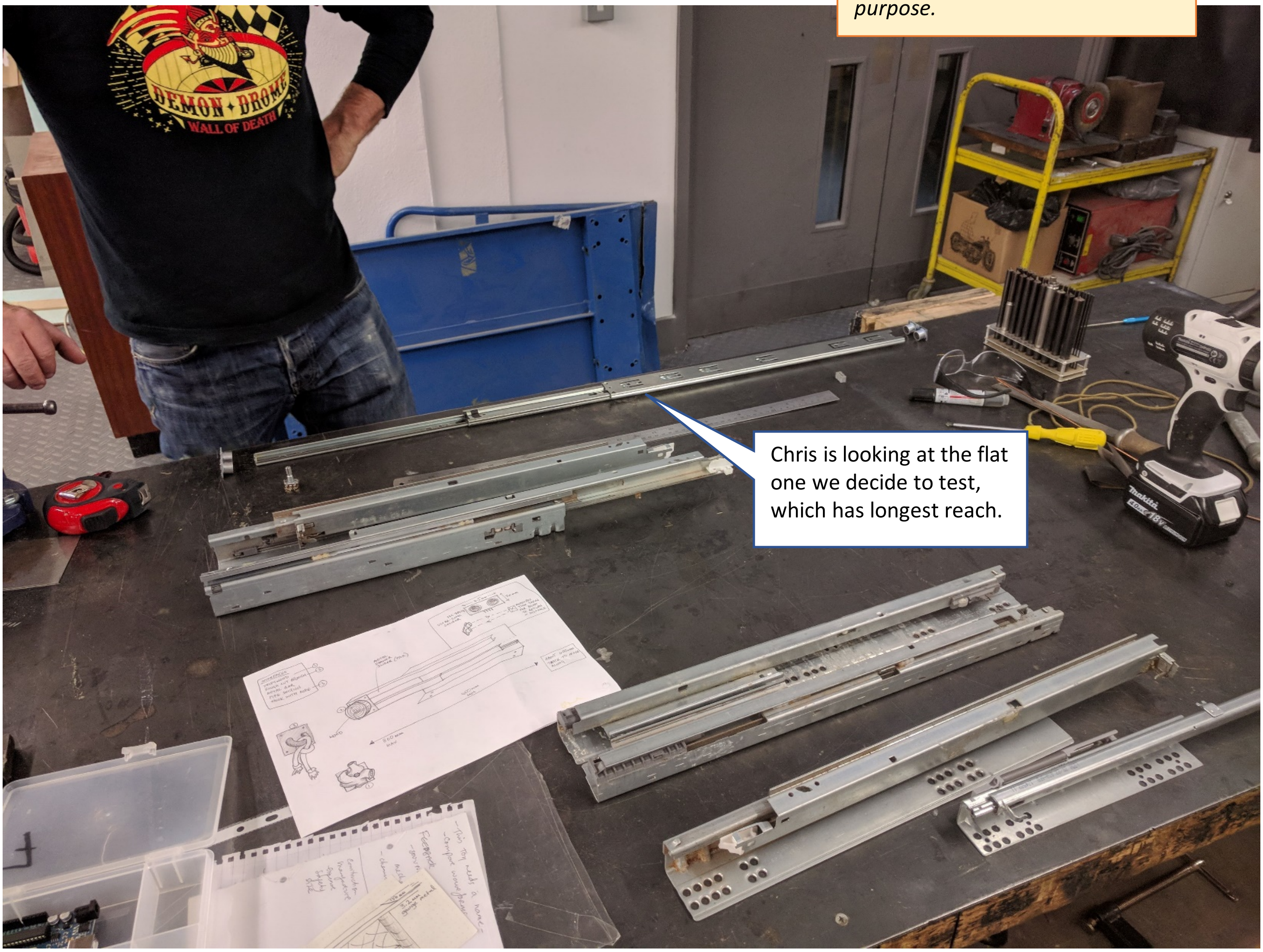


At first Chris thinks 2 sliders joined might be more stable. There's about 400mm movement in a construction twice that length.

BLOGPOST: 1 May 2019
Rough sketches to show concept for an elephant analogue input device using ultra-sonic sensors mounted at either end of a repurposed drawer slider.

The HC-SR04 sensors measure time taken for pulse to travel to obstacle and back, which can be converted to a distance, thereby indicating how much the slider has been pushed. We need to construct a housing that enables elephants to manipulate the slider without destroying it...

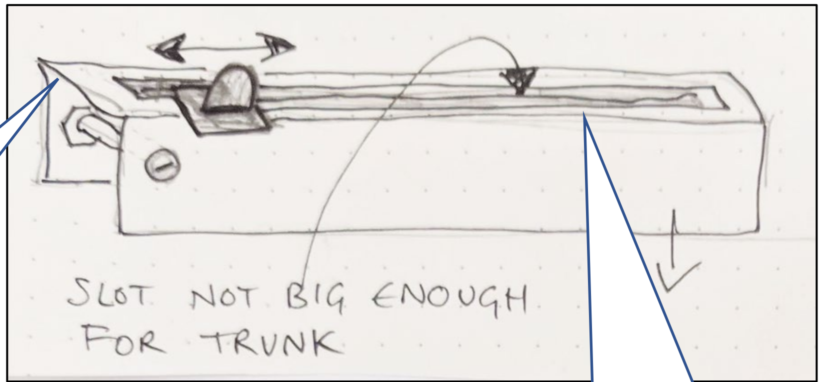
Here's Chris Hosegood in workshop at The CASS - https://www.londonmet.ac.uk/schools/the-cass/ - examining the various drawer sliders I've brought to see which might be fit for purpose.



Chris is looking at the flat one we decide to test, which has longest reach.

MAY 2019:
SLIDER 3 : DRAWER / INFRA-SONIC

CHALLENGES – How do we attach the device to the top of the balcony? How do we stop dirt getting into the slot?

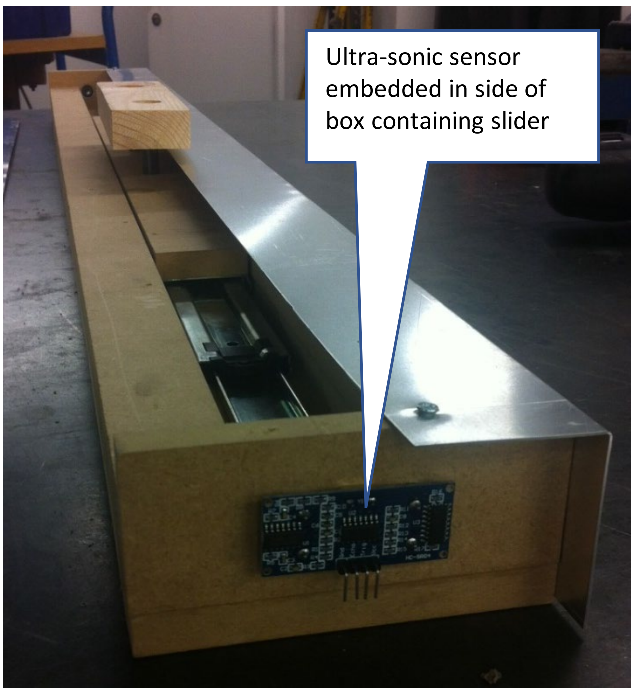


Device is mounted on a steel/aluminium square profile sheet that slots over top of balcony rail. Holes for long bolts to then pass through wire grille.

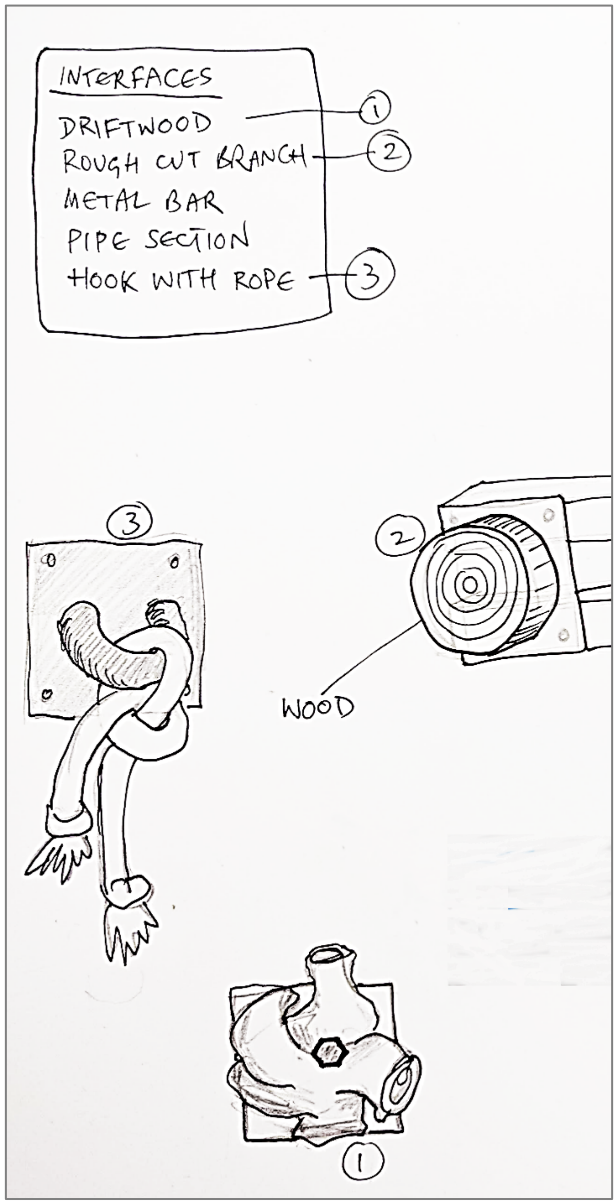
The slider protrudes from a thin hole that trunk can't enter. Use draught excluders to protect entrance.

This doesn't have to look like a human slider – it should appeal to an elephant. So there are many possible fixings that could be used on the "knob" part that moves the sliding part underneath.

Chris builds a prototype from MDF and aluminium sheet, so I can test functionality with Arduino and sensors.



Ultra-sonic sensor embedded in side of box containing slider



Draft excluder

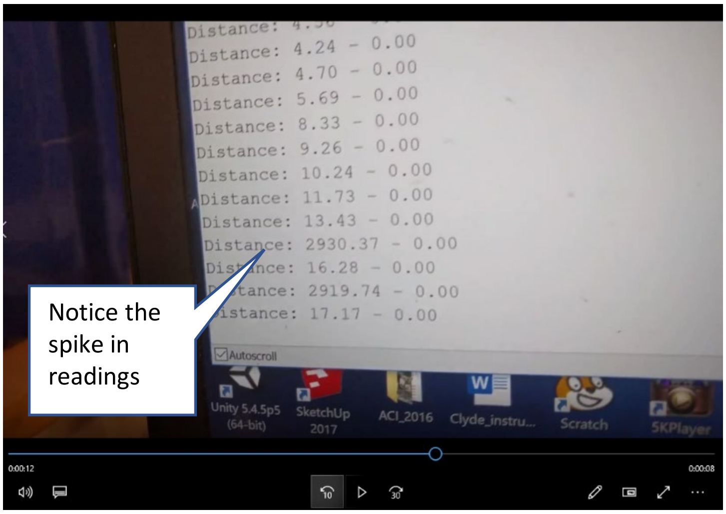
JULY 2019:

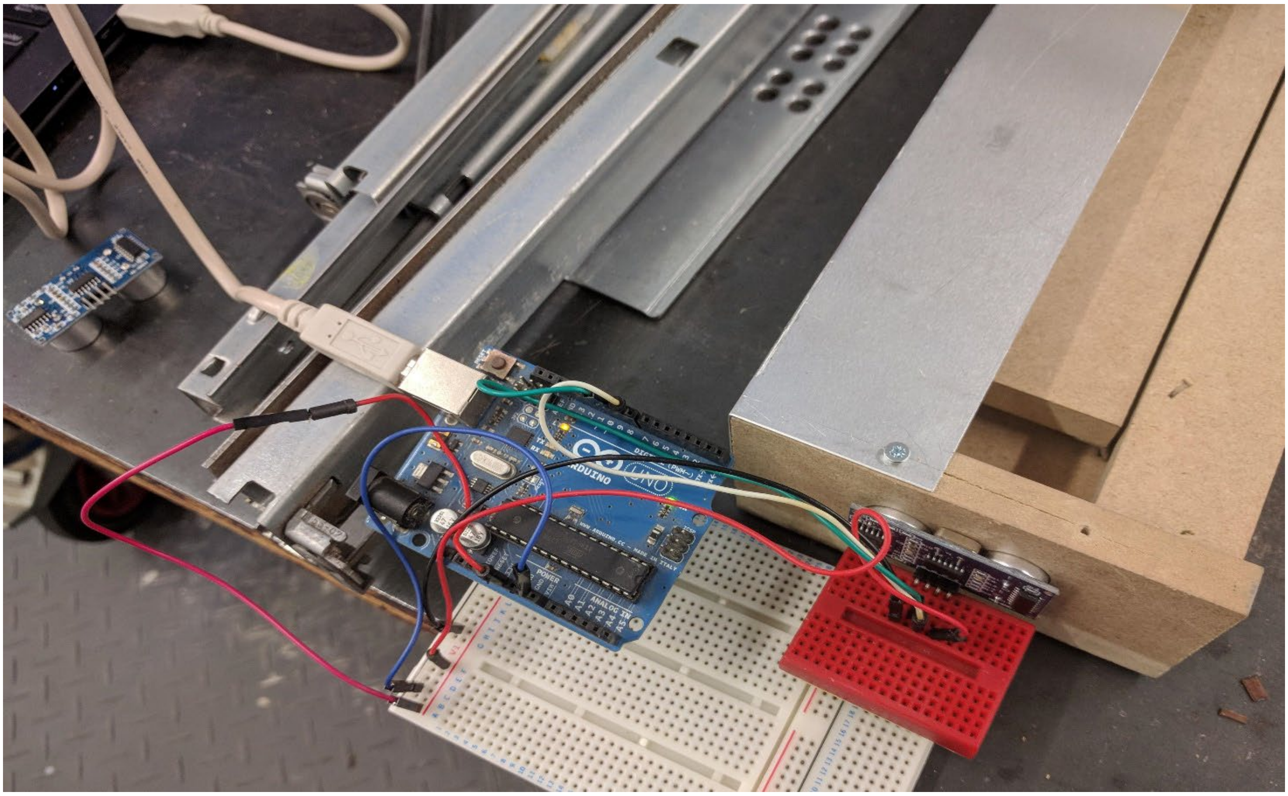
SLIDER 3 : DRAWER / INFRA-SONIC

Hooking the sensor to the Arduino and taking readings as we slide the knob along

4/7/2019
We tested for functionality at different stages by hooking the ultra-sonic sensor to the Arduino and taking readings as the slider moved. Notice the spike in readings - they need to be smoothed to provide accurate mapping to an acoustic signal.

Also, as the slider moves along the track away from the sensor (over 100mm), there's a point at which the sensor fails to pick up object, so the internal alignment needs to be adjusted slightly.



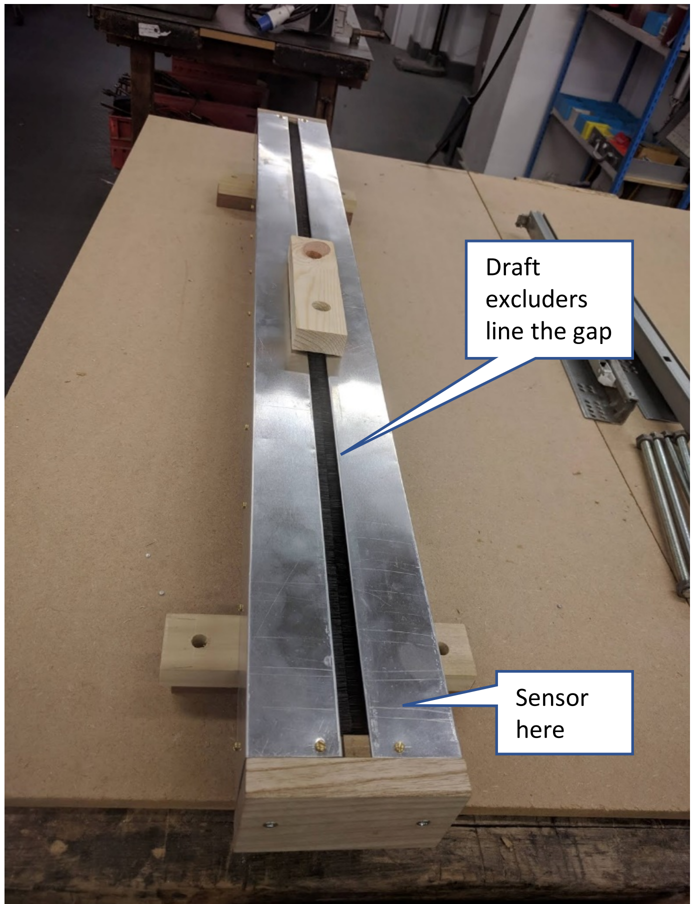


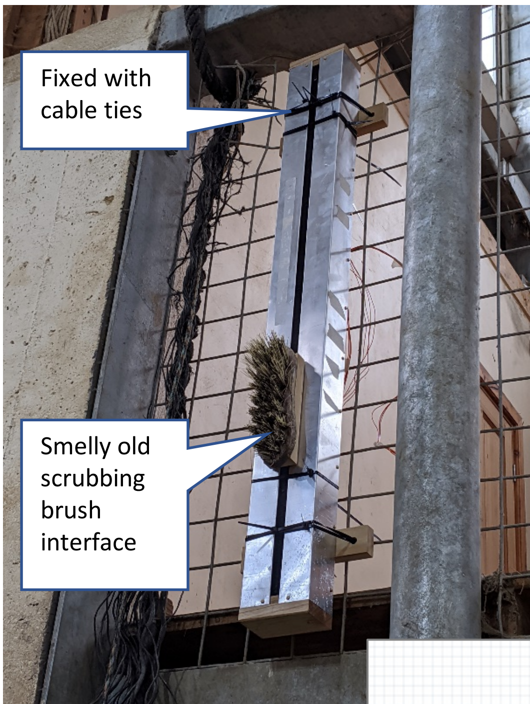
CHALLENGES
- Bands of aluminium to attach device to grille, because we don't want to compromise the balcony integrity with bolts through the handrail.
- Garage length draught excluder for the gap.
- Weakest point where wood attached to thin slider – so needs a lip to prevent elephant tugging this and breaking the join.
- Close (under 100mm) is accurate, but as slider moves away the readings falter, because thin moving part not lined up with sensor – either thicken wood at end or reposition sensor.
- Second sensor reading invalid, check the code!
- Aluminium lip is sharp so Chris will do a double bend both to strengthen and soften for trunk tips.
- Selecting suitable output that changes dynamically and quickly when the signal changes.

JULY 2019 / FEBRUARY 2020: SLIDER 3 : DRAWER / INFRA-SONIC

BLOGPOST: 4 July 2019
Here's the finished slider made by Chris at The CASS. It is constructed from MDF and aluminium sheet to keep it light; looks very sleek and professional - appealing to humans! Lengths of garage draft excluder have been fixed inside slot to keep dust and dirt from entering. There may be some issues with fixing, as the 2 wooden support Chris has bolted to the frame would still allow room for a curious trunk to curl around the body of the slider. It's important to fix flush with a strong surface so elephant can't grip around an object to pull it off.

Still some ideas to consider with regard to the wooden slider component, which will be made into something a bit more interesting for an elephant... Possibly brush, tree root, rope...



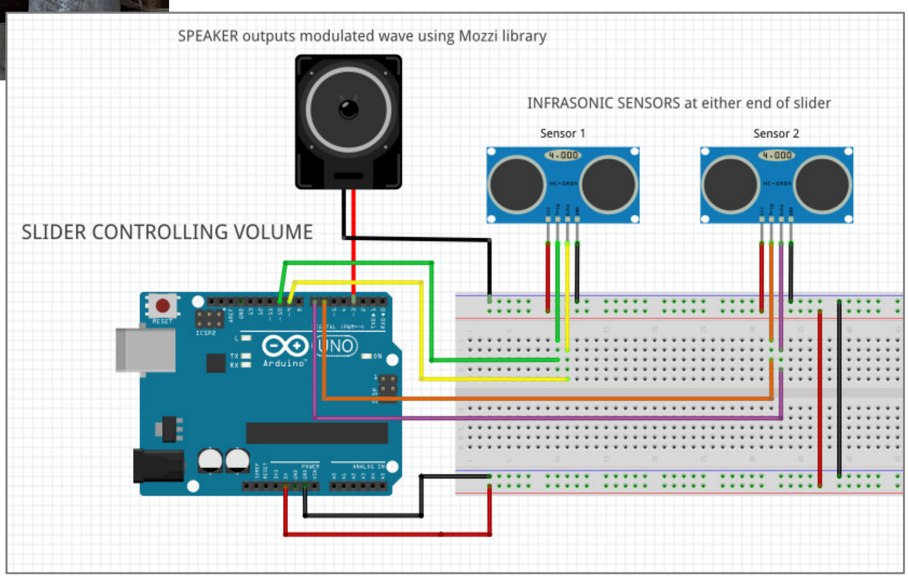


BLOGPOST: 29 Feb 2020
Here's the slider, installed on the balcony rail within reach (on Friday). I've attached an old scrubbing brush to the sliding part to make it more interesting. Wires from the sensors at either end go through railing to Arduino.

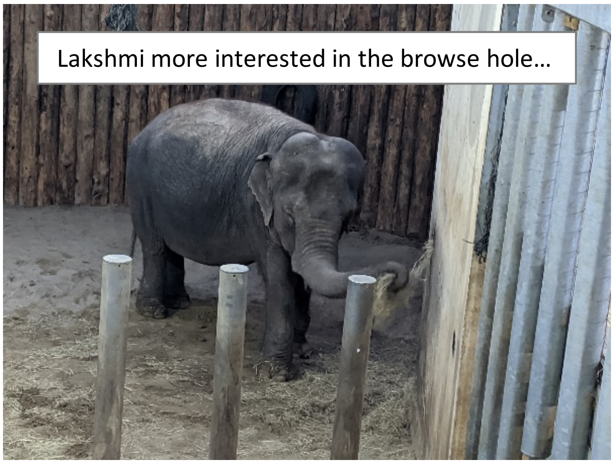
The slider is a volume control - zero noise at bottom (default position) and progressively louder modulated wave as it is pushed upwards. Speakers are on balcony just behind the device.

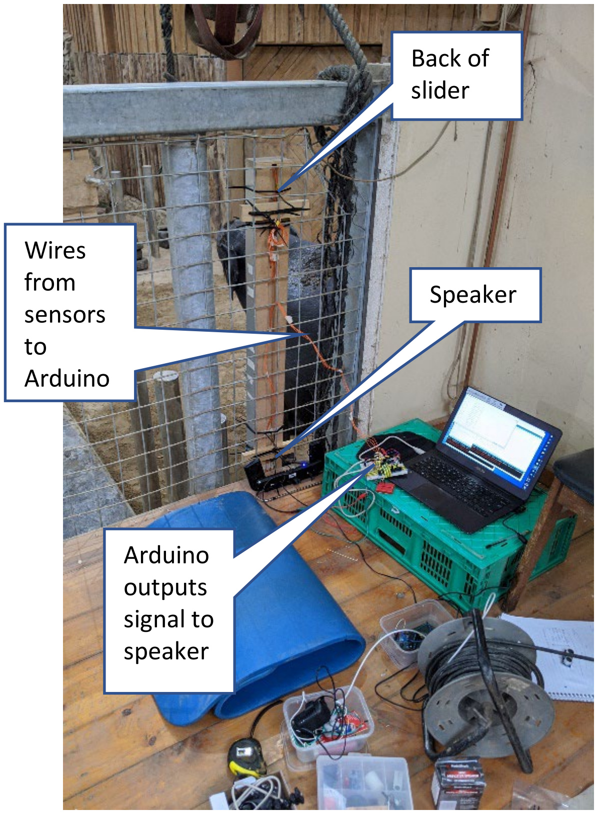
Mozzi

audio synthesis library
for Arduino
https://sensorium.github.io/Mozzi/



FEBRUARY 2020:
SLIDER 3 : DRAWER / INFRA-SONIC


Lakshmi more interested in the browse hole…



On the non-elephant side of the balcony rail, I've set up Arduino connected to laptop connected to speakers (and also a little dash-cam in case a trunk comes this way).

The slider was designed to be horizontal, but mounting it turned out to be difficult as we couldn't use the balcony rail. We're convinced that moving objects are more intrinsically interesting to manipulate as control elements, as well as having clearer affordance for the elephants.

29/02/2020
The keepers were keen for the elephants to try out the device, and managed to encourage them without using bananas (!) but Lakshmi definitely seemed more involved with finding straw than creating sounds. However, you can't rush an elephant.


Lakshmi with Br. Peter


… and Br. Simon

FEBRUARY 2020:
SLIDER 3 : DRAWER / INFRA-SONIC

Lakshmi plays with the slider on Saturday morning…

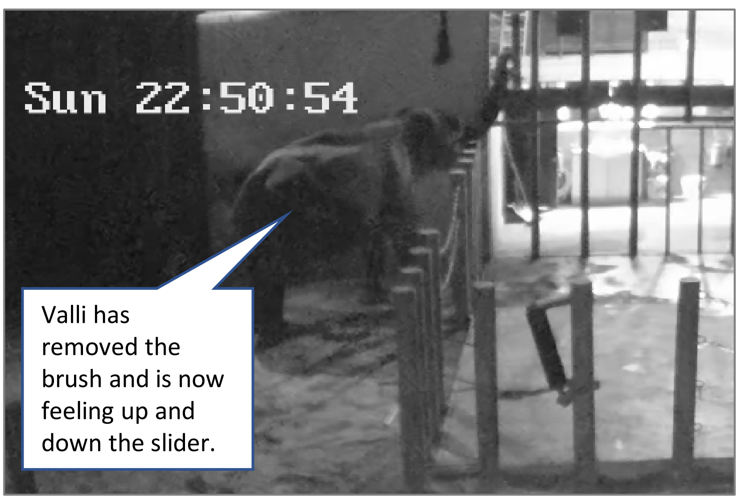
29/02/2020
Later that evening, both elephants went over to explore the slider when no-one was around. On Saturday morning, Lakshmi gave herself a surprise when she triggered the sounds, and shortly afterwards we switched off the electronics.

After I left, Brother Stefan told me that Valli subsequently removed the scrubbing brush and used it to groom herself. She then spent some time investigating the slider - they sent me the night footage showing her doing this. So there's definitely hope for an analogue control, but we will reconsider the design since the balcony area now only for bathing and we need to choose a different accessible location.

The slider was designed to be horizontal, but mounting it turned out to be difficult as we couldn't use the balcony rail.

Night footage shows that the elephants are more willing to investigate when we've all gone away and they are left on their own.

MEDIA LINKS
- Valli plays with slider the evening after installation, then Lakshmi tries in the morning. https://vimeo.com/406648348
- A few days later, Valli plays dismantles the brush handle and uses it to scratch her head! https://vimeo.com/406586191



Input: Analogue

FEBRUARY 2020:

SLIDER 3 : DRAWER / INFRA-SONIC

		INSIGHTS				
DEVICE	**Date**	**Testing - tech - sensors**	**Output**	**Elephants - materials - dimensions**	**Location**	**People**
START		**DRAWER SLIDER**		**LARGE WOODEN HOUSING?**		**HELP FROM CASSWORKS for CONSTRUCTION**
SLIDER 3 - DRAWER / INFRA-SONIC	May-19	**Ultra-sonic** sensors working well with good range... requires decent power so need **mains supply** for Arduino.	Acoustic	**Re-purpose** existing drawer slider - good mechanism.	**Bespoke** for balcony railing - but location had to change. Which meant that horizontal aspect was lost.	**Useful to make a blueprint** for design, think about all the aspects
		Sensors. Some issues with capturing 2 signals in tandem in order to determine distance from both ends.		**Elephants engage when we're not around** - don't like being told what to do...		**Understanding embedded tech.** Without the possiblity to work side-by-side, it was difficult to emphasise importance of sensor angle - minute changes altering the readings. **Teamwork.** Similarly, we had some misunderstanding regarding suitable fittings for the device.
				Aluminium good strong lightweight material, but needs expertise, equipment and workshop.		Great to establish contact and work with colleagues at Londonmet.
				Affordance - elephants interested in brush but didn't push slider knob UP - at first.		**Keepers** very keen to show elephants what to do as usual!
				Robust housing - undamaged. Brush was removed at first, but then left in place after being refitted.		
CONCLUDE		**MORE WORK WITH AUDIO**		**MOVING PARTS / INTERESTING TACTILE QUALITIES / LEAVE IN SITU**	**BETTER CONSIDERATION OF FITTINGS**	**CASSWORKS RULES / TEAMWORK**

The design is functional and the elephants seem to engage with the device even when there is no acoustic output – or perhaps they prefer it without noises. **We're convinced that moving objects are more intrinsically interesting to manipulate as control elements, as well as having clearer affordance for the elephants.**

Working with colleagues at CASS Works was successful up to a point – the final slider could not have been constructed without Chris' expertise, and he was very helpful. However, handing over the blueprint for someone else to build was awkward, because the actual crafting process has been very organic and helped to provide insights on the design – this element was therefore lost by relying on technical support. Additionally, Chris preferred to work alone on the brief, whereas it would be have been better if we could have worked together, enabling me to test electronics and troubleshoot the design and position of sensors during the build.

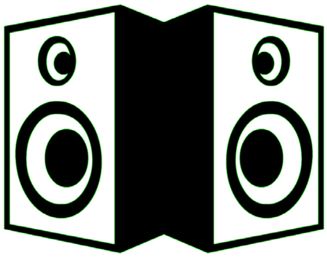
A different challenge arises with creating bespoke pieces for individual institutions. The designs are not immediately transferable, and if there are changes in the environment (such as the balcony being out of bounds for toys), we need to go back to the drawing board for fittings.

There are many interesting options to explore and we hope to continue our relationship with the elephants.

APRIL 2020: FOLLOW-UP EMAIL FROM SKANDA VALE

Dear Fiona,
We got a nice clip of Laksmi playing with the sliding brush a couple of weeks ago, in the middle of the night. She showed no sign of wanting to destroy it, a good sign!

Output



CONTENTS

Trying to imagine what sort of output could be interesting for an elephant was the biggest challenge. We explored a range of options, eventually returning to the idea that tactile and audible modalities are very closely linked – especially for an elephant.

This workbook present our research into different kinds of outputs for enrichment systems. It is divided into tangible (mostly water) and acoustic output. The associated input devices are explained in the INPUT workbook.

Output: Tangible

RATIONALE & EARLY CONCEPTS

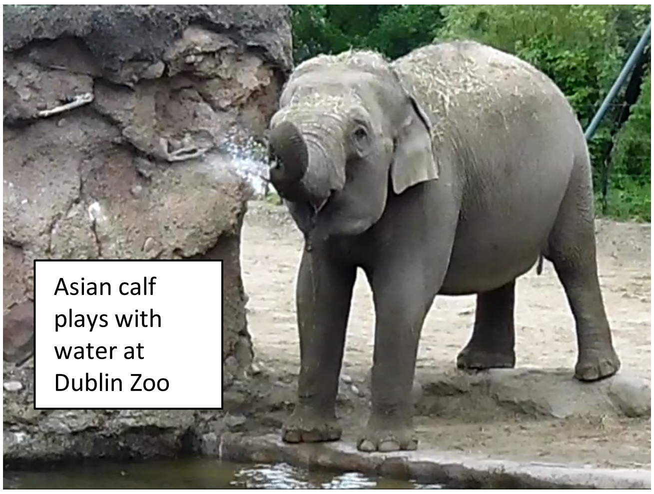
African elephants playing in waterhole, Etosha National Park, Namibia

Asian calf beside pond at Twycross Zoo

Opal having a mud bath at Colchester Zoo

MEDIA LINKS

- Valli enjoying a shower / bath https://vimeo.com/406533865



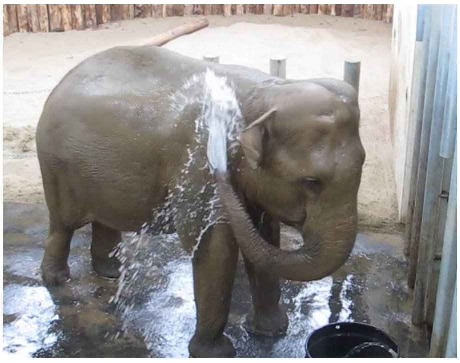
Asian calf plays with water at Dublin Zoo

Valli with new waterfall at Skanda Vale

Elephants enjoy tactile stimulation – water, mud, dust baths – and water is a vital resource like food. What's not to like?

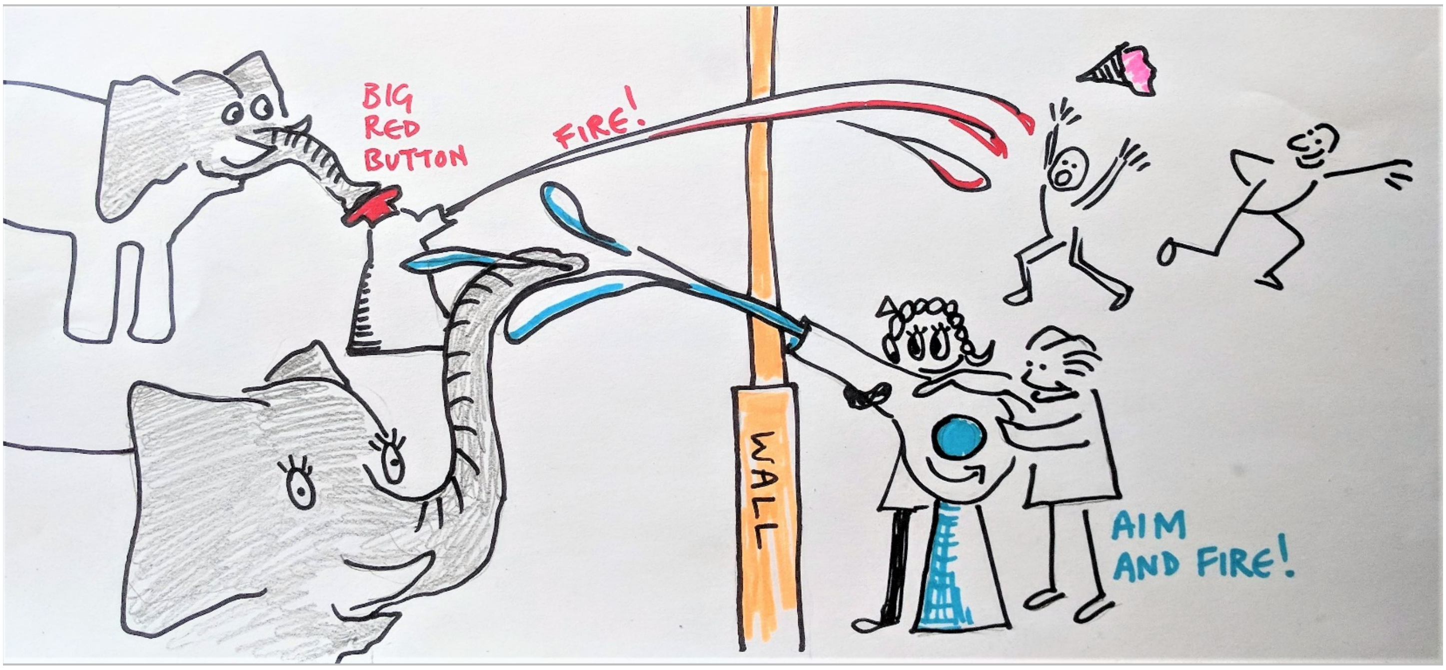
Some of our concepts were designed to offer tangible output, initially in the form of water and subsequently other forms of feedback.

Valli having a splash during bath time



RATIONALE & EARLY CONCEPTS

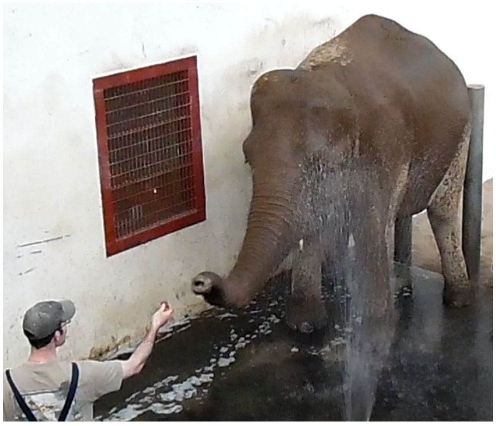
Playing with the visitors



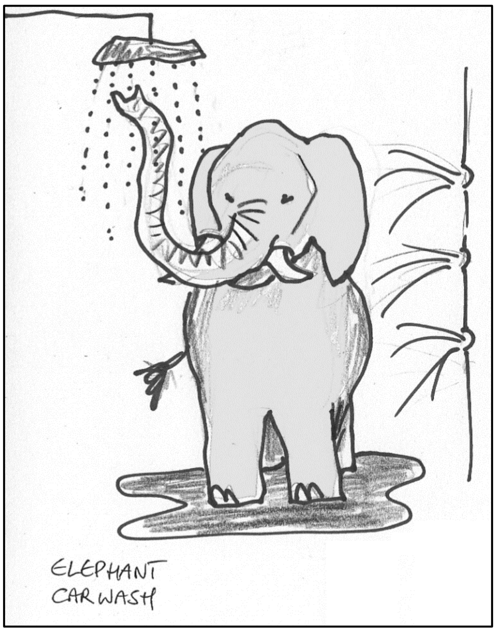
https://www.youtube.com/watch?v=c27SWQA5o-Q
It's probably okay as a holiday experience in Sumatra...

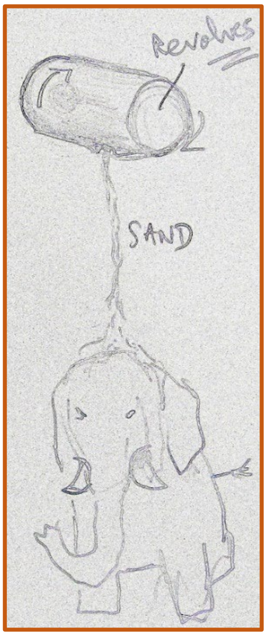
WATER CONTROLS

Skanda Vale keepers like the idea of shower controls...	Other ideas for tactile stimulation



When Valli has a shower, one of her keepers is in charge of the hose pipe, so she doesn't have too much **control** over the experience.





RATIONALE & EARLY CONCEPTS

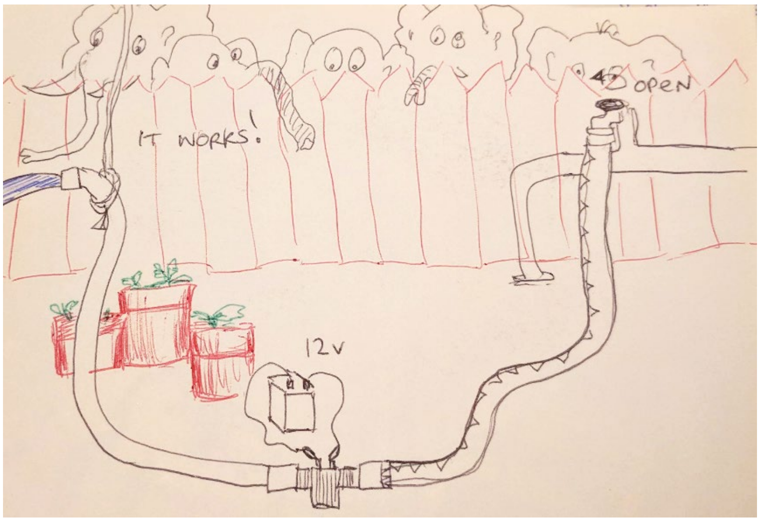
		INSIGHTS			
DEVICE	**Date**	**Testing - tech - outputs**	**Input**	**Elephants - reactions to output**	**People**
Sand barrel		**Difficult** to re-fill. Requires heavy machinery?		**Unknown.**	**Keeper suggestion.**
Car (elephant) wash				**Unknown.**	**Keepers** are enthusiastic - have same idea.
Playing with visitors		**Practical difficulties** associated with construction of apparatus on elephant side of enclosure wall, including water supply.		**Cross-species play. I**nappropriate for elephants to play with humans.	**Visitors** unlikely to appreciate being soaked. Skanda isn't a zoo in any case, and Valli deosn't have visitors - it would be the keepers getting soaked!
WHERE DID WE START?		**CARWASH (SHOWER)**			**KEEPER COOPERATION**

The rest of this section shows our attempts to create **shower controls** for Valli.

Water was used as an alternative output to audio in two of our interactive devices. This was a keeper request, but we also thought that because water is a fundamental resource that all animals require, it might be the best initial output to use in order to test a novel control system.

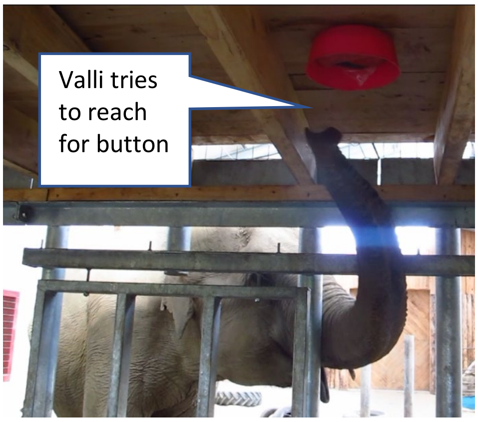
In fact, Valli already has a small pool inside her shed (see below) but at present the shower facility can only be activated by her keepers.

MAY 2015: FIRST WATER PIPE

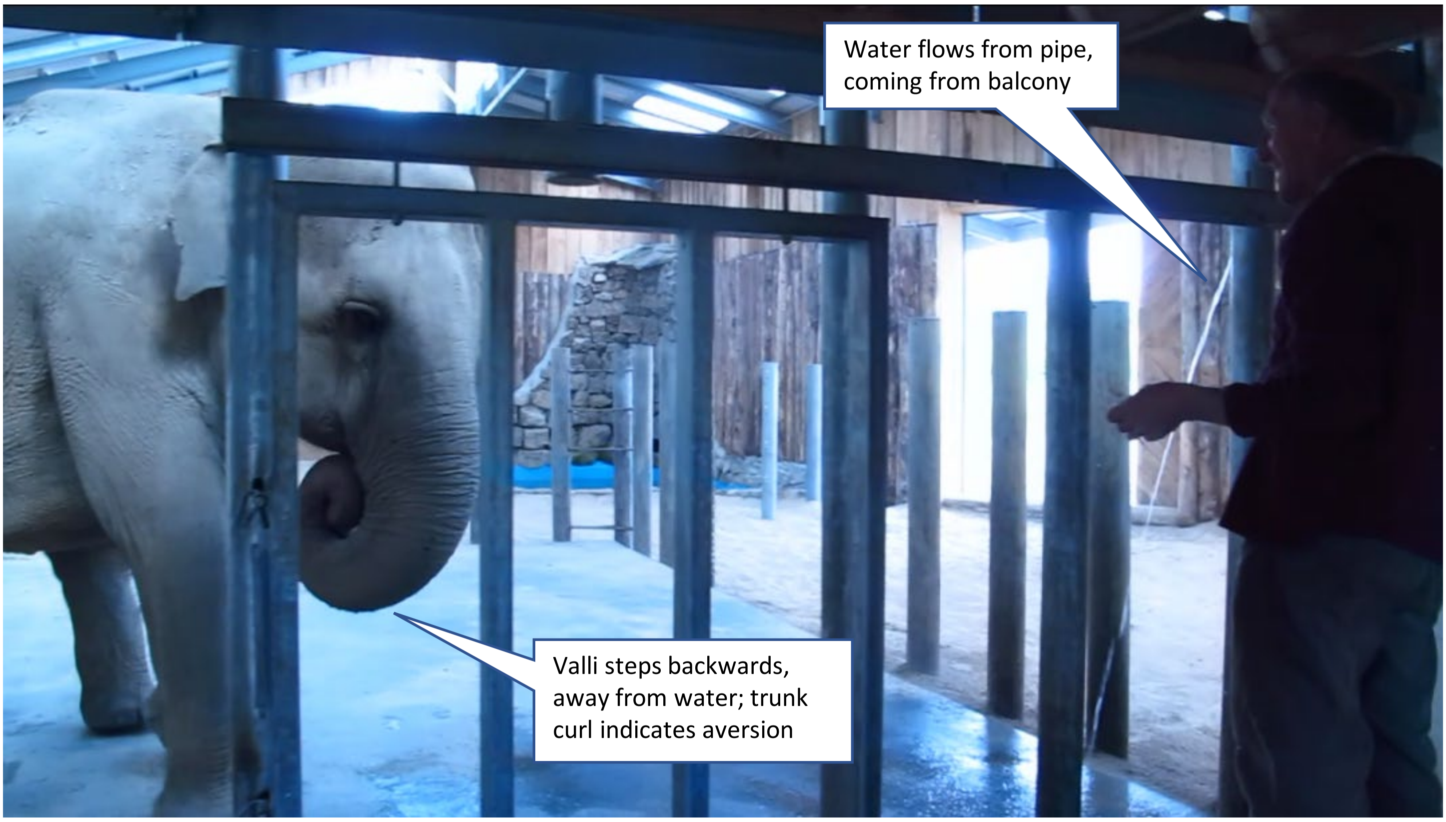


System successfully tested in garden with full mains water pressure.

At Skanda Vale we connected a hosepipe to the tap and fixed it to balcony floor. The valve intercepted the pipe so that the final length of pipe stretched beyond the valve. When the valve was triggered, there was a short time delay before water reached the end of the pipe and came out.



MEDIA LINKS
- Valli triggers the hosepipe
  https://vimeo.com/406352738
- Valli's initial reaction to water
  https://vimeo.com/406329765



MAY 2015: FIRST WATER PIPE

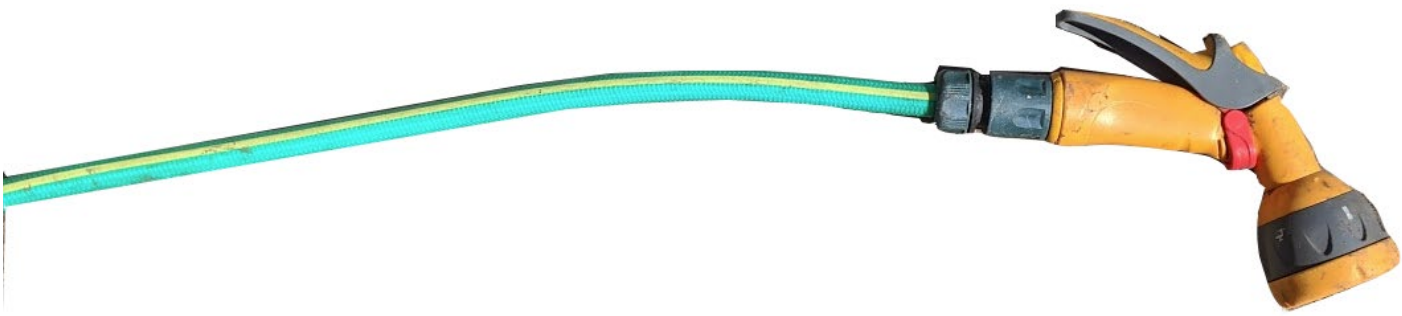
DEVICE	Date	INSIGHTS Testing - tech - outputs	Input	Elephants - reactions to output	People
START		**ANALOGUE**		**WATER**	**METHODS**
WATER 1	May-15	**I don't understand what's happening.** The time gap between touching a "button" and triggering an event was much too long. We could not expect Valli to make the association between the two events – her activity and the resulting water supply.	Push-to-make	**Vote with your feet.** One important aspect of our testing procedure was that Valli always had the option of whether to participate or not. In this case, she simply walked away, which signified her displeasure or disinterest. In any case, she was exercising her right to choose. So if she doesn't appreciate water, let's try with audio again.	
				Trunk v Hose. If you have a trunk, why would you need a hosepipe?	
CONCLUDE				**AUDIO**	

After this attempt, we continued with our development of devices that offered **acoustic output**. This work is presented in the next section - ***Output: Acoustic***.

By December 2015, we had tried several prototypes and realized that Valli had a strong interest in the tangible properties of our interventions. This row shows the conclusions after testing our Motor Rumble device:

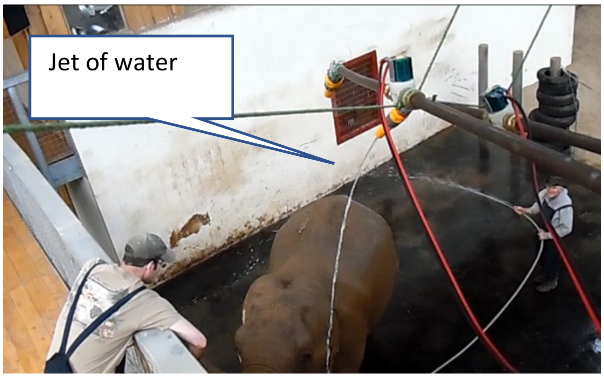
CONCLUDE		**HAPTICS / TACTILE**	**WATER**

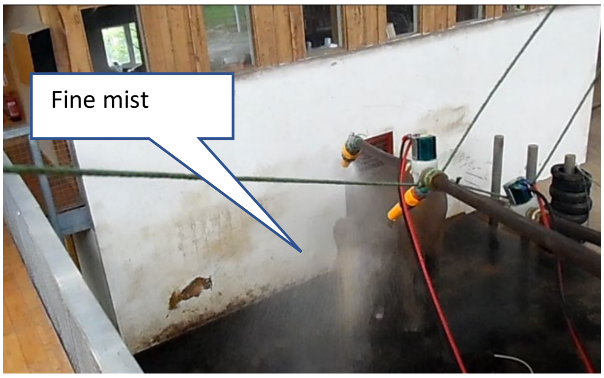
Since the keepers were still keen to try shower controls, we decided to have another go with **water** as an output the following year, because water is tangible as well as being a crucial commodity for survival …



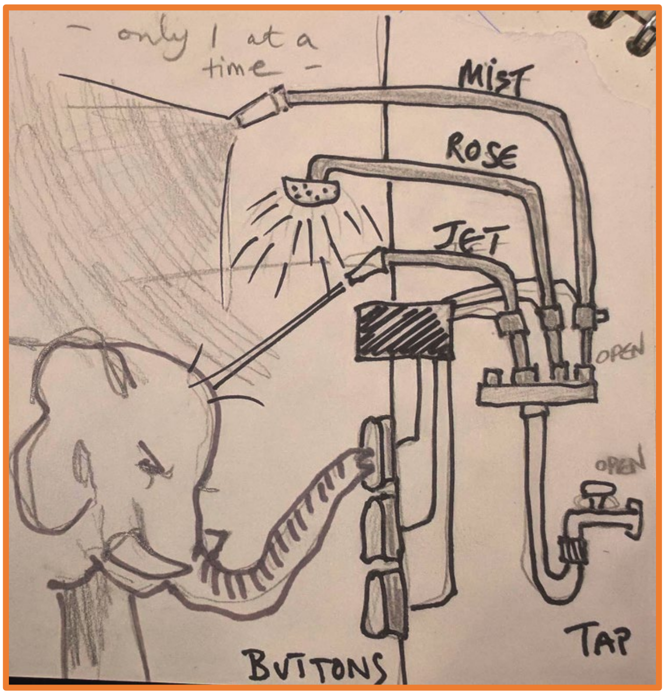
MAY 2016: SECOND WATER PIPE

Second attempt with a shower, using 2 buttons to trigger 2 different types of spray – jet and mist.





Spray and jet options from shower buttons



Concept poor – we failed to appreciate that Valli doesn't like unexpected sprays of water from above…

MEDIA LINKS
- Valli triggers a shower https://vimeo.com/406585860
- Valli avoiding the overhead water https://vimeo.com/406585812

12/5/2016
One button activated a jet of water, which hit Valli unexpectedly on the back and was not very popular. She left the shed and refused to come back in.

The keepers concluded that she would have more interest in controlling a water supply if she was thirsty or already in the middle of a bath, so we tried again after her walk. The high jet was not trunk-accessible and will be lowered to a visible height.

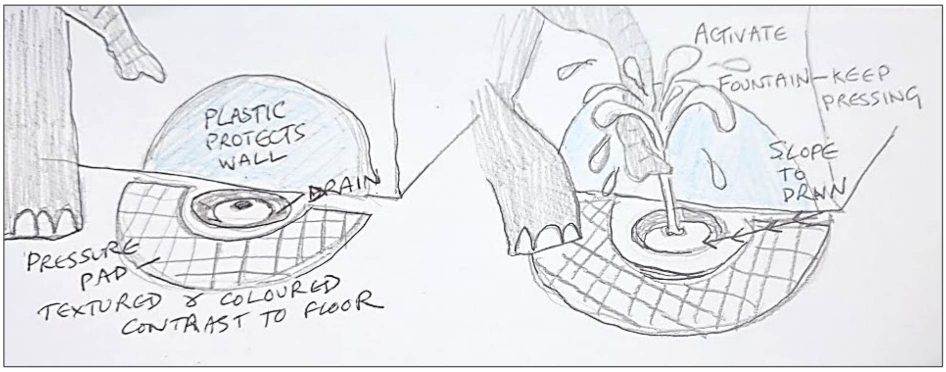
When Valli had been showered by the keepers and was already wet, she appeared to be quite content to touch the other button - activating a fine mist spray.

Valli doesn't mind water when she's wet!

MAY 2016: SECOND WATER PIPE

Valli is happy to investigate buttons, but as soon as water comes out, she's off. We try again after lunch but she backs away and heads for the exit.

Valli is walking backwards



CONCEPT

This is a speculative design for a small water fountain that could be activated by an elephant using pressure pads around the base. She would be able to see it and control it, and the water would be in a suitable location for drinking.

There are multiple issues regarding manufacture and location, as this would involve some serious plumbing and excavation of the substrate in the enclosure, so it's not a suitable system for rapid prototyping and testing.

Our explorations of water supplies dried up after this, as Brother Stefan lost interest in developing a shower control for Valli, as he believed she would not use it.

MAY 2016: SECOND WATER PIPE

		INSIGHTS			
DEVICE	**Date**	**Testing - tech - outputs**	**Input**	**Elephants - reactions to output**	**People**
START				**HAPTICS / TACTILE**	**WATER**
WATER 2	May-16	**It's different in Wales...** The importance of testing devices in the field – we couldn't anticipate Skanda Vale water supply not being high-pressured and consistent enough to activate the pump.	Tactile	**Cold water isn't always pleasant.** It took us a while to realise that having a jet of cold water unexpectedly hitting you might not be a very good experience. Why did it take us so long? Valli's bath time usually involves a tub of warm water.	
				Surprises are stressful. We were convinced that Valli would appreciate the water – but usually elephants approach water supplies because they already know they exist and can see what's there. If water comes from above, it's rain and they can probably sense it long before it starts. If a keeper points a hosepipe, it's part of the usual bathing ritual and routine behaviour, so again, they know what's going to happen. Unpredictable behaviours and events are known to be stressful.	
				Lack of control. By comparison, my terrier always jumps straight into the pond to cool down and have a swim, but she hates going out in the rain... I infer that she prefers to be in control of getting wet. What we accidentally ended up doing was giving Valli LESS control of what was happening	
CONCLUDE				**MORE CONTROL - NO MORE COLD WATER**	

We stopped trying to develop shower systems after this – but the interest is still there, as Brother Stefan recently (2020) suggested we try to make a control for the elephants' existing pool shower, which they are happy to use regularly.

Our design work re-focused on providing auditory enrichment at this stage – the sequence of audio experiments and prototypes follows...

Output: Acoustic

RATIONALE & EARLY CONCEPTS


African elephants at the waterhole


African woodland elephants browsing at Howletts Animal Park


Tembo and Zola, African elephants at Colchester Zoo


Small Asian herd at Twycross Zoo


Asian elephants browsing at Dublin Zoo

Elephants are social animals. They can produce and hear infrasound, often using low frequency rumbles to talk to each other. Sometimes in captivity they lack the opportunity to communicate with a large extended family.

Auditory enrichment has the potential to offer elephants both sensory and cognitive stimulation. This section presents various concepts we developed for devices with acoustic output, with links to samples and videos of elephants' reactions.

Valli used to live by herself with humans (now she has a companion, Lakshmi).

She's a temple elephant at Skanda Vale Ashram in Wales, where she enjoys a lot of freedom to roam in the countryside – accompanied by her keepers. She was our first elephant user, who has tested many prototypes!

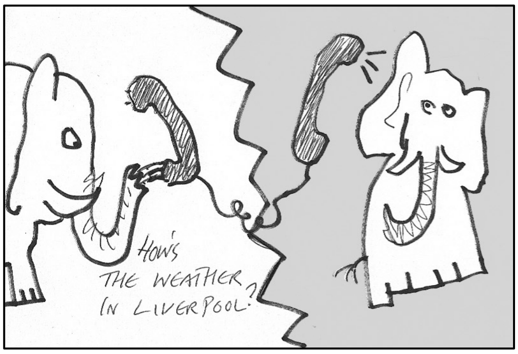
MEDIA LINKS

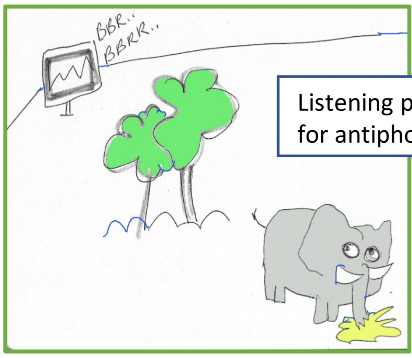
- Soundcloud sample: Colchester Zoo background music played all day https://soundcloud.com/user-607238008/2014-colchester-zoo-soundtrack

RATIONALE & EARLY CONCEPTS

Call and response. "Simon Says" type game but with audio sequence could mimic antiphonal calling. Solitary elephants could be introduced to conspecifics in zoos around the UK. **BUT** animal experts from EWG suggest that the sound of unknown elephants is likely to be stressful rather than enriching. Also confusing if no physical presence.

ELEPHONE / Skype for elephants



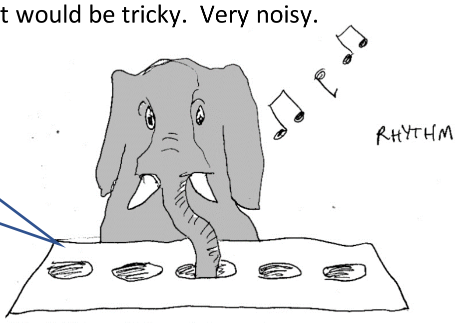


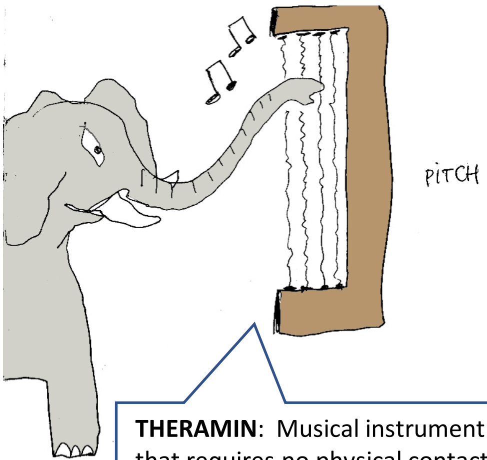
Listening post + microphone for antiphonal calling

CAMPANOLOGY
WHY? Opportunities for cooperative play; pulling branches is normal behavior; massive bell gives low pitch; may be possible to capture movement with accelerometer for digital system.

BUT manufacturing and installing a system that would withstand an elephant would be tricky. Very noisy.

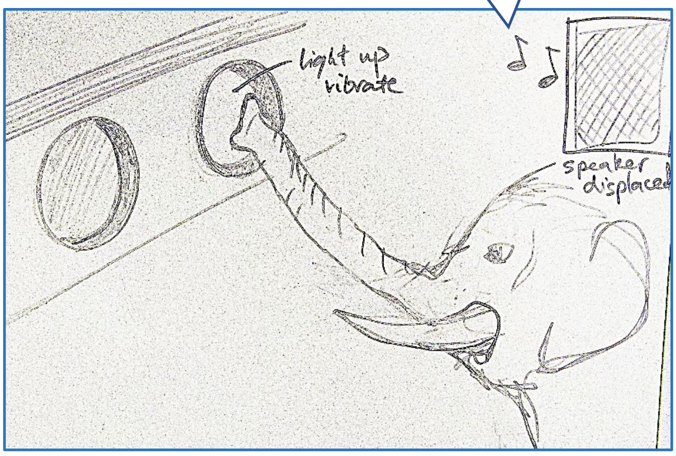
It's all about offering a choice…





THERAMIN: Musical instrument that requires no physical contact – uses capacitance sensing and outputs a variable digital signal.

Multimodal – visual, acoustic



BIG CHALLENGE
What kind of acoustic output would be interesting for an elephant?

RATIONALE & EARLY CONCEPTS

		INSIGHTS			
DEVICE	**Date**	**Testing - tech - outputs**	**Input**	**Elephants - reactions to output**	**People**
		Huge range of possibilities. Start with something small and simple and achievable.		**One size doesn't fit all.** Auditory output is pervasive – what to do in a crowd?	
				Deception. Disembodied elephant sounds – confusing because no smell or presence.	
				Stranger danger. EWG advised against vocalisations because of stress caused by unknown conspecifics. Suggest alternative environmental sounds – e.g. bird or ungulate	
WHERE DID WE START?		**Generate rumbles - try digital ouputs at range of lower frequencies.**		**Elephants communicate with each other a lot; would a solitary elephant be scared or stressed by strange new sounds in her environment? No crowd problem though.**	

We generated many ideas for auditory enrichment and different kinds of systems that might interest an elephant. However, the first stage was to check if unusual noises in her enclosure would be stressful or upsetting for Valli. So the first experiments involved playing a range of different kinds of sounds through loud speakers in the elephant shed and monitoring Valli's reactions.

We were particularly interested in finding out if she showed any interest in **lower frequency audio**, since lower frequencies are representative of an elephant's usual rumbling.

OCT 2014: TESTING LOW FREQUENCY AUDIO

BLOG POST: 22 Oct 2014
Skanda Vale is a multi-faith ashram in the Welsh countryside, who keep a temple elephant, Valli. I went to visit Valli and her keepers at the Ashram on 21st Oct, invited by Brother Stefan, who is interested in developing some novel enrichment for her.
…

Sound system in adjacent room

Test large speakers on balcony

MEDIA LINKS
- Digging It – Ancien https://www.youtube.com/watch?v=6V845EpvXWI
- Desert Rain – Outback https://www.youtube.com/watch?v=j72LqeLcHFM
- Healing and Relaxation with Didgeridoo - Reiki Music Academy https://www.youtube.com/watch?v=h0U9C5FnnxA
- How LOW Can You Go? - Bass Mekanik - Tracks that follow range from 80Hz - 10Hz https://www.youtube.com/watch?v=hRqPyHvXIWU&list=OLAK5uy_k0k-uK6DIsDsxyDU1dg5fErU1TVSkMI74&index=20

22/10/2014
…
We take Valli for her second long walk of the day - up into the woodland - where she shows how Welsh elephants can do some strenuous clambering up hills if there are juicy leaves on offer.

When we return, it is time to play Valli some audio, to check that the different sounds do not make her scared. B. Peter says that a wildlife program terrified her when she was younger; B. Stefan says that she does not enjoy drums. It is likely that she can hear the drums being played at the temples at the bottom of the hill. There are 6 sets of prayers every day. B. Danny says he often plays her Grateful Dead, while B. Peter plays Bluegrass.

I have a selection of didgeridoo tracks by Ancien, Outback, Reiki Music Academy and some Bass Mekanik tracks from their album "Sonic Overload", which includes very low frequency tracks, designed to test people's speakers. There are samples ranging from 100Hz down to 10Hz. We connect my laptop (which can't produce any sound lower than about 80Hz, but which can nevertheless play the MP3s) to Skanda Vale speakers and play Valli some didgi music and some low freq samples. I video her reactions. She appears to be listening.

OCT 2014: TESTING LOW FREQUENCY AUDIO

Valli stands under balcony near the speakers while sound samples are played. But is this motivating for her?

22/10/2014
Valli is not scared by the sound production and her keepers are enthusiastic about giving her an opportunity to control the production of audio. When she understands that she can control an aspect of her environment, and is confident doing this, the plan will be to use similar buttons/controls to allow her to control other things, such as the temperature of the wall, the lighting, showers or dust baths etc.

Interpretations of Valli's reactions were provided by her keepers, who were present during playback and observations. 60-80 Hz seemed to be most relevant.

Table 4: Audio samples played to Valli

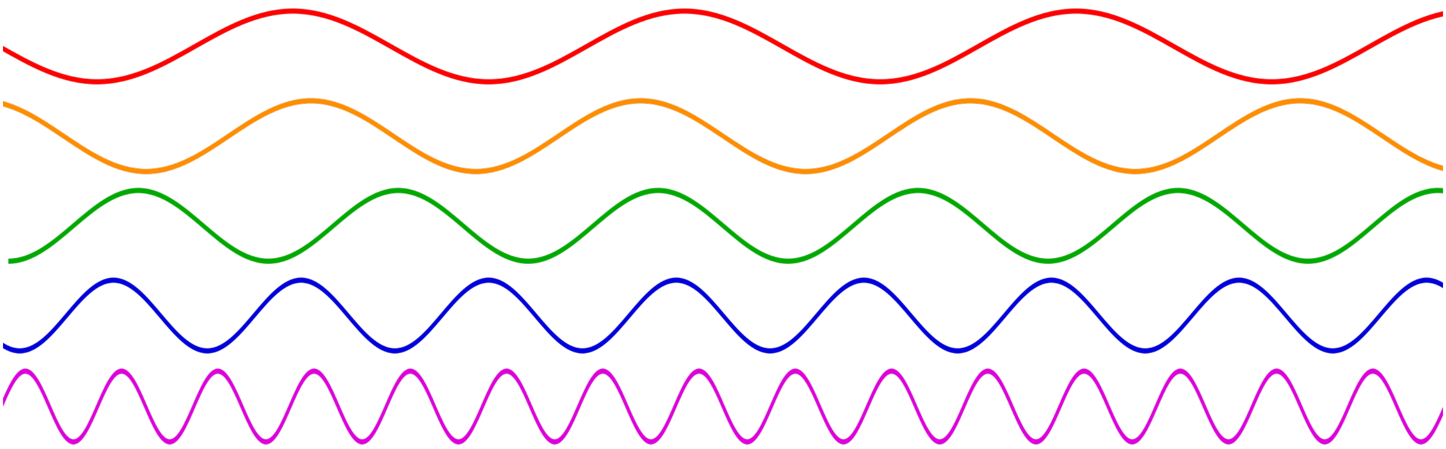
Tracklist	Duration (Seconds)	Reaction
Desert Rain – Outback (didgeridoo and other instruments)	5.22	Moves to one side to position herself so she can hear; comes close to speakers and investigates with trunk
Healing and Relaxation – reiki Music Academy (pure didgi, very monotonous)	4.52	Standing still near speakers, head down, eventually moves away
80-71 Hz Frequency – Bass Mekanik (Sonic Overload)	0.09	Valli appears to show most interest at this range
70-61 Hz Frequency – Bass Mekanik	0.09	Valli appears to show most interest at this range
50-41 Hz Frequency – Bass Mekanik	0.10	Little interest
40-31 Hz Frequency – Bass Mekanik	0.10	Stefan can hear, I can not
30-21 Hz Frequency – Bass Mekanik	0.10	Inaudible, unclear if speakers can play
20-11 Hz Frequency – Bass Mekanik	0.09	Inaudible, unclear if speakers can play
10-1Hz Frequency – Bass Mekanik	0.11	Inaudible, unclear if speakers can play
60-69 Hz 10 seconds each frequency	1.40	Valli appears to show most interest at this range
70-79 Hz 10 seconds each frequency	1.40	Valli appears to show most interest at this range
80-89 Hz 10 seconds each frequency	1.40	Little interest
90-99 Hz 10 seconds each frequency	1.40	Little interest
100-109 Hz 10 seconds each frequency	1.40	Little interest

OCT 2014: TESTING LOW FREQUENCY AUDIO

		INSIGHTS			
DEVICE	**Date**	**Testing - tech - outputs**	**Input**	**Elephants - reactions to output**	**People**
WHERE DID WE START?		**Generate rumbles - try digital ouputs at range of lower frequencies.**		**Elephants communicate with each other a lot; would a solitary elephant be scared or stressed by strange new sounds in her environment? No crowd problem though.**	
AUDIO TESTS	Oct-14	**Human sensory limitations.** Don't know whether low frequency audio is actually being generated without a tech capture device / fancy microphone (now 2019 app might work). Perhaps try first with something we can definitely hear... SINE WAVE?	NONE	**No stress.** Valli seems vaguely interested in some of the sounds, but only for short period. Keepers think 60-70Hz is interesting for her. The audio doesn't appear to worry her.	**Keeper.** Hard to appreciate what she thinks of the music – requires keeper intelligence / analysis.
				Interpretation. Problem of obtaining feedback from an elephant. This is why it's important to offer controls so she has a choice what to do.	
CONCLUDE		**SINE WAVE**		**CONTROL & CHOICE**	**KEEPERS**

The **keepers** were involved in all aspects of testing and keen to see how Valli reacted. It was clear that she had no problem with new noises in her environment. We decided to proceed with crafting an **interface device** to see if she was able to trigger an acoustic output herself, thereby giving her more control over the situation (she could choose whether or not to trigger).

The output would be a **sine wave**, because that's very easy to generate using a microcontroller and a piezo buzzer – it's essentially an electronic pulse sent at different frequencies to the output device.



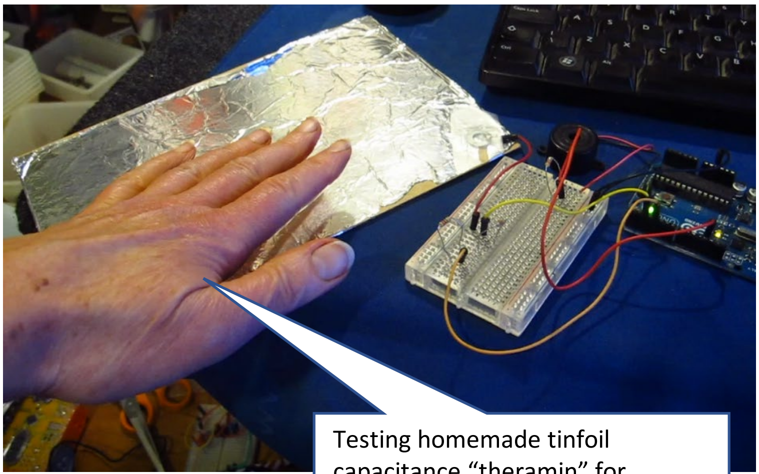
MARCH 2015: SINE WAVES

Our first test of an interactive acoustic device with an elephant was the pipe button. The output/feedback from the pipe trigger was a sine wave, generated by a piezo element – a small device that vibrates at a specific frequency determined by a signal sent from microcontroller. It's possible to vary the frequency in real time according to analogue readings from a sensor – creating a "theramin" device where player controls pitch.

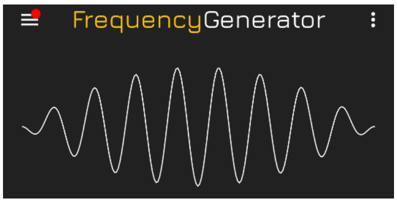
The pipe button used capacitance sensing, which can produce analogue readings as grounded object (hand, trunk) approaches. However, we wanted **digital buttons** (on/off) for simplicity, so sensor was calibrated to have a threshold, at which point buzzer was triggered.

MEDIA LINKS

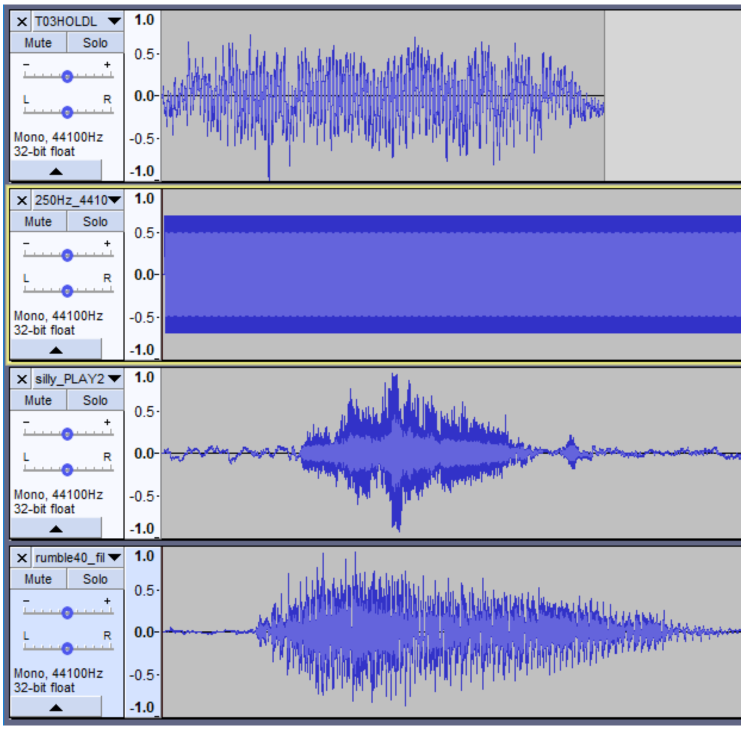
- Tinfoil capacitance test: https://vimeo.com/364638571
- Use Online Tone generator to generate a sine wave at a specific frequency.- https://www.szynalski.com/tone-generator/



Testing homemade tinfoil capacitance "theramin" for analogue output. Calibration required to vary pitch – will it work in the elephant shed?



Sine wave was generated using Arduino code to make Piezo component vibrate at correct frequency.



Female African elephant rumble-coo

Sine Wave

African elephant playful trumpet

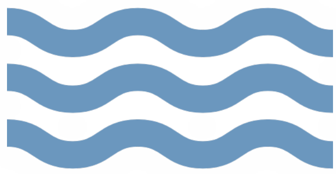
African elephant rumble

Waveforms across time (timbre) for some elephant calls and for a sine wave...

Sine waves are unlikely to be cognitively stimulating for an elephant.

MARCH 2015: SINE WAVES

		INSIGHTS			
DEVICE	**Date**	**Testing - tech - outputs**	**Input**	**Elephants - reactions to output**	**People**
START		**SINE WAVE**		**CONTROL & CHOICE**	**KEEPERS**
SINE WAVES	Mar-15	**Varying pitch.** Unfortunately, the pipes were not long enough to test this concept. Would be good to try this in future with an analogue control mechanism.	Pipe button	**Boring sine waves.** Sine wave has no interest for elephant? Lacks interest, complexity, harmonics, too high pitched from piezo buzzer. Try a different kind of output that we know is desirable, such as water.	**Skip the snacks.** It's impossible to know what choices are being made and why if food involved – highlighted in Digital Inputs.
CONCLUDE		**ANALOGUE**		**WATER**	



We did wonder about whether Valli could understand that she was controlling something without physical contact? (Capacitance sensing does not require touch) An earlier concept had been a Theramin – as sensor readings fluctuate, signal is modulated which alters sound emitted by instrument, which is played using both hands in vicinity of the aerial – but it's hard enough for a human to control one, far less an elephant. She might enjoy it in the same way it's possible to enjoy splashing paint around with no sense of creating anything meaningful. However, offering her a chance to tinker with quality of audio may offer insight into preferred sounds a system could use for agreeable acoustic feedback.

It was at this point that Skanda vale keepers made their requests for shower controls for Valli – more of a utilitarian than a playful system, but we tried to accommodate them while testing different input devices, as documented in section ***Output: Tangible***. This row shows our conclusions after attempting the first water output device (May 2015).

CONCLUDE				**AUDIO**	

Valli's reluctance to engage with cold water being sprayed unexpectedly on her head during this test led us to return to **acoustic outputs**…

SEPTEMBER 2015: AEROPHONE SAMPLES

So how does an elephant create such interesting sounds with complex waveforms? **Using its trunk...**

Humans have developed long-bored and stringed instruments that generate sounds with low frequencies and distinctive timbres – didgeridoo (early audio tests), tuba, trombone, double-bass, contra-bassoon, organ pipes. They lack the **40,000 muscles** of a trunk, which most probably contribute to the quality of the calls produced by an elephant, yet these human instruments may be more exciting to play with than a sine wave.

Is a trunk like this?

Media links
- Elephants react to didgeridoo performance 2019: https://www.youtube.com/watch?v=FNpEwnofQcs
- Elephants and didgi 2008: https://www.youtube.com/watch?v=OTuCPZVqTag
- Tuba: https://www.youtube.com/watch?v=mvs1TVMN_Ew

An open-ended wind instrument (aerophone) has longitudinal standing waves trapped inside the tube, causing harmonics to build when air is vibrated by blowing reed. Different tones when length of tube changes, various controls.

Manufactured instruments are designed to have uniform timbre, whereas a traditional didgeridoo is made from a eucalyptus branch hollowed out by termites, thus has individual variations; primarily rhythmic, not melodic.

MEDIA LINKS
- Trombone: https://soundcloud.com/user-607238008/2012-trombone-by-linton
- Didgeridoo: https://soundcloud.com/user-607238008/didgeridoo-sample
- Elephant rumble greeting: https://www.elephantvoices.org/images/documents/1537/190_file_1.mp3

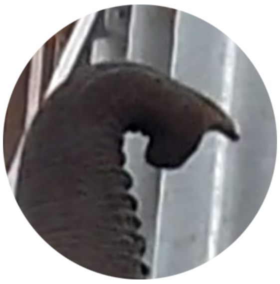
SEPTEMBER 2015: AEROPHONE SAMPLES

		INSIGHTS			
DEVICE	**Date**	**Testing - tech - outputs**	**Input**	**Elephants - reactions to output**	**People**
START				**AUDIO**	
AEROPHONE SAMPLES	Sep-15	**Response time.** Tech – not fast enough response from Arduino (microcontroller input) to Processing output on pc. Tech delay therefore fails user – elephant can't make connection between action and reaction from system.	Pedal	**Mapping actions to outputs.** Make the system feedback instantaneous.	**Keeper control.** Brother Stefan triggered the button.
				Valli didn't seem to like the tuba sample. It may have been too loud, or just a surprise…	
CONCLUDE		**AVOID PROCESSING**		**INSTANT FEEDBACK / NO SAMPLES**	

One of our main insights from this was that the orchestra samples we tried were of no interest to Valli and in fact they were played so abruptly that they gave her a shock. Stefan had to trigger the audio because she wouldn't engage with pushing the pedal button. Moreover, the samples were being played via Processing, connected to the Arduino via a Serial port. There was sufficient delay between input sensor activation and Processing playing the clip for the mapping between action and output to be unclear.

It was also obvious to us that we had been considering the interface problem from a very human perspective – think light switch ON/OFF and just make a HUGE one! Nope.

As a result, we decided to look into **haptics** as a way to offer instant feedback without having awkward moving parts. We knew that elephants have very sensitive trunk tips, which meant that it might be possible to provide her with some subtle feedback.

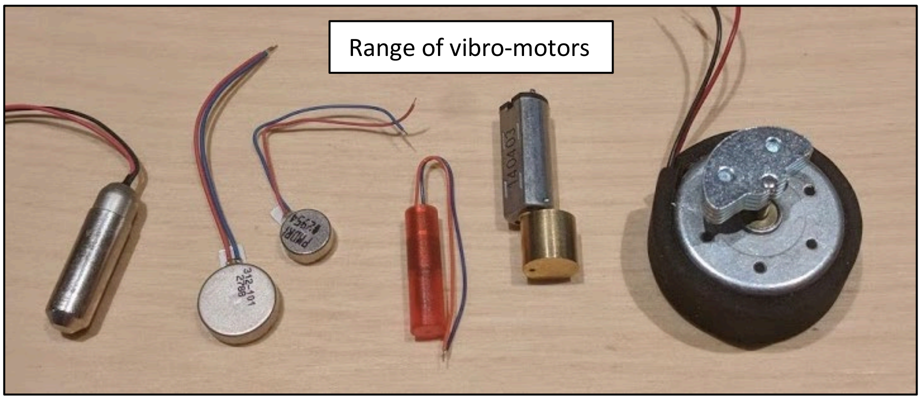


DECEMBER 2015: MOTOR RUMBLE

CHALLENGE
How to ensure that Valli maps her action to the output?

We needed to make the output instantaneous and make the button responsive to indicate to an elephant that something happens when you trigger it…

MEDIA LINKS
- Valli feeling button surface: https://vimeo.com/146186217



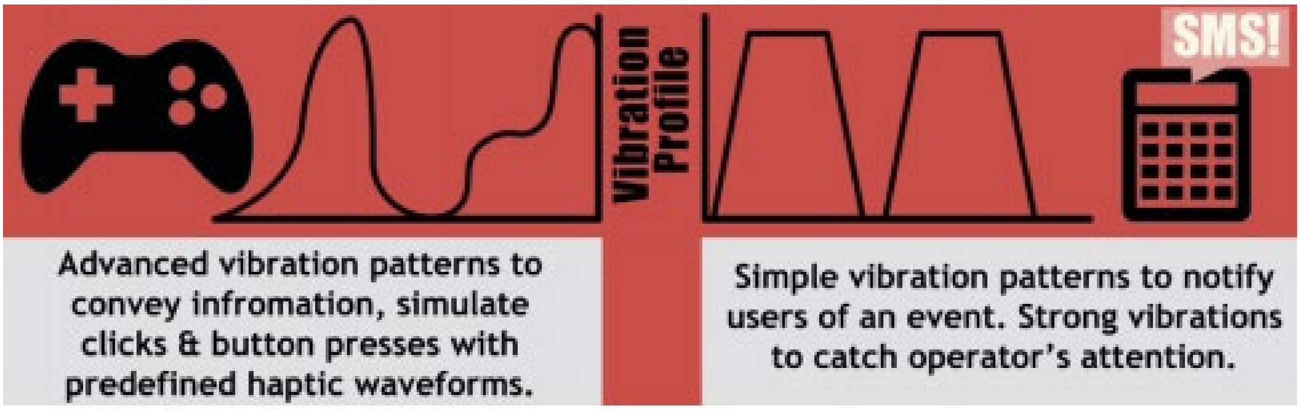
Trunk deep inside button to feel vibrations

Vibration alerts are common in phones, and simple to deploy – it's a scuppered motor, which creates a pulse when activated. Ordered a range of small vibro-motors from **Precision Microdrives** – a London-based company who were very helpful over phone when we were enquiring about motor specs.

CHALLENGE
Can a human appreciate how an elephant hears/feels (using feet, nose, ears) – mixed modalities – is this synaesthesia?

Clearly Valli was FEELING the vibration, but could she also hear it? Most likely.

Infographic from Precision Microdrives Haptic integration Guide.
https://www.precisionmicrodrives.com/haptic-feedback/



DECEMBER 2015: MOTOR RUMBLE

		INSIGHTS			
DEVICE	**Date**	**Testing - tech - outputs**	**Input**	**Elephants - reactions to output**	**People**
START		**AVOID PROCESSING**		**INSTANT FEEDBACK / NO SAMPLES**	
MOTOR RUMBLE	Dec-15	**Power.** Easy hook-up motors to Arduino, but draws a lot of power.	Vibrotactile	**New directions in interface design.** Expanding the modalities of UX design is very topical, with innovations in haptics and body-sensing and even digital smells (for humans). It's early days and although fascinating, beyond scope of this project. Message to self - keep in focus!	**Water output?** Keepers still keen to explore a shower control.
		Output v feedback. How to distinguish between output and feedback from a button – is there a difference here?		**Valli likes a buzz.** Keepers all confirmed that she seemed to enjoy feeling the haptic panels. Any associated acoustic output was ignored, but the buttons seemed to generate interest in themselves. This clearly points us in the direction of haptic controls and tactile feedback, which we hope to explore in the future.	
				Merging modalities. Holistic approach to sensory perception. Could feeling be the same as hearing for an elephant? Particularly at low frequency…	
				Experimental. Keep in mind that interactive devices for elephants have few precedents, which means there is not much previous work to build on. Good novelty value, potential for discovering more about elephants (and ACI), but we need to be careful about expressing generalisations derived from specific investigations.	
CONCLUDE				**HAPTICS / TACTILE**	**WATER**

This experiment gave rise to a lot of new ideas concerning haptic enrichment devices (see IDEATION workbook). However, although such devices might have been interesting to touch/hear, the element of control was limited. Either touch it or not. Something that enabled an elephant to moderate the vibration frequency and amplitude would be good, but this is the same challenge we have with audio output.

The subsequent prototype was **another shower control attempt**, documented earlier. Valli's reaction to the water supply was not so enthusiastic, as we have explained, so we then moved back to acoustics at a different venue.

Lisa Yon from EWG contacted me about working with one of her graduate students, Ashley, who was hoping to investigate elephant acoustic preferences and the potential for auditory enrichment. We visited different zoos to try and find working partners; Noah's Ark near Bristol were willing to allow us to install a **radio** system for their elephants…

JULY 2016: ELEPHANT RADIO

BLOG POST: 30 June 2016
...
Sounds
Lisa and Ashley wanted to do a test with elephants whereby they are offered control over sounds that play - using the same sounds that were tested in a previous study at Blair Drummond. In that study, the elephants were played 3 different sounds (whale song, classical music and heartbeat) and their responses were noted. I asked which classical music track was used, but was not able to clarify this.

Intuitively, the nature of the music seems to me to be important - eg. Brahms v Wagner - hardly the same kind of noise. I checked online and found some footage and stories about both zoo-housed and sanctuary elephants apparently listening to and enjoying live musicians playing classical tracks:
www.theguardian.com/science/2008/nov/17/elephants-zoos-classical-music-elgar
www.youtube.com/watch?v=n50R3UqLhZI
http://www.musicforelephants.com/

Lisa said it might be appropriate to play elephant noises to the elephants (although I had been advised earlier not to do this) so I checked www.elephantvoices.org for some "playful" sounds that elephants had made in a happy context, finding a selection of low rumble-coos, made by mothers to pacify their offspring. Then Lisa suggested we should drop heartbeat in favour of a classical track.

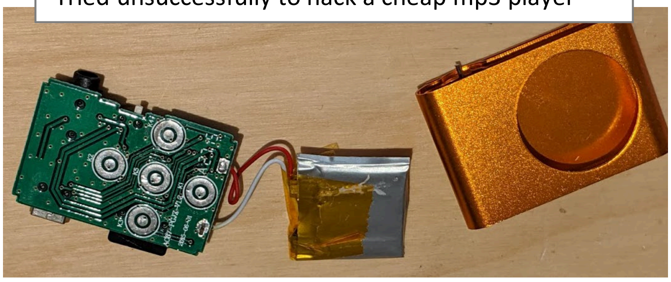
In the end, I selected [1] rumble-coo; [2] humpback whale song; [3] short clip from Bach D Min for 2 violins.

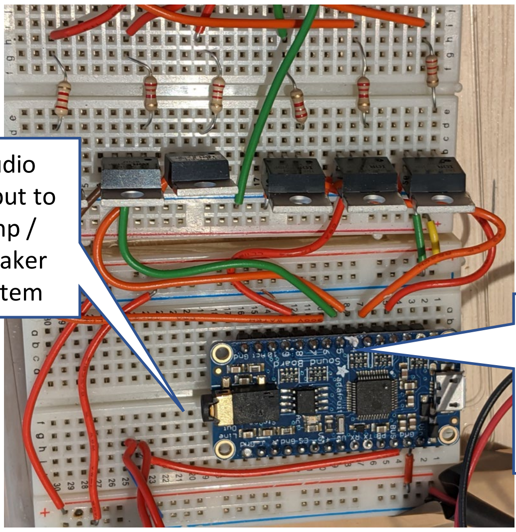
MEDIA LINKS
- Rumble-coo: https://www.elephantvoices.org/images/documents/1492/145_file_1.mp3
- Humpback whale: http://www.oceanmammalinst.org/songs/hmpback3.wav
- Bach D Minor for 2 violins: https://www.youtube.com/watch?v=ILKJcsET-NM

- Paul Barton plays Bach on piano for elephant: https://www.youtube.com/watch?v=VOr2O0FfpT8

Finding a way to output the audio samples was a challenge since we couldn't rely on a laptop to play files. We used an Adafruit Sound Board, which can store small files in WAV/OGG format and then be connected to an input – such as a button – to trigger the playback. We were using a capacitive sensor shield to connect multiple radio buttons.

Tried unsuccessfully to hack a cheap mp3 player

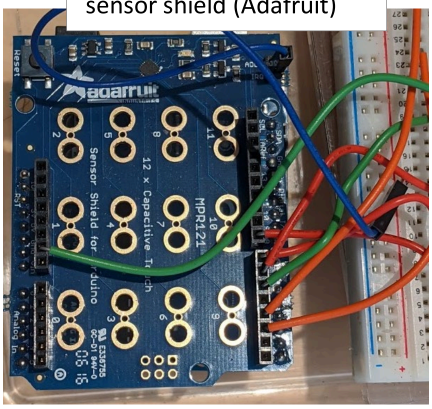




Audio output to amp / speaker system

ADA2133 Audio FX Sound Board

MPR124 capacitive touch sensor shield (Adafruit)



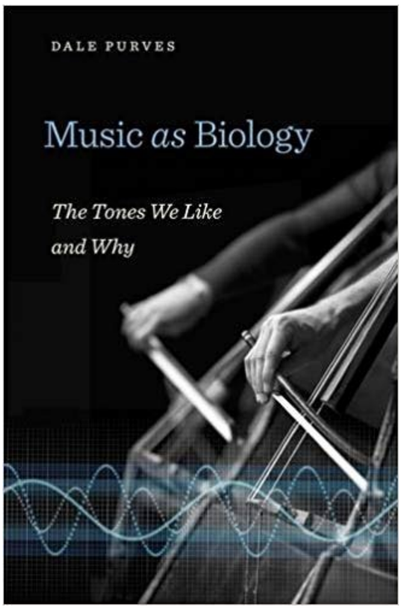
JULY 2016: ELEPHANT RADIO

		INSIGHTS			
DEVICE	**Date**	**Testing - tech - outputs**	**Input**	**Elephants - reactions to output**	**People**
START				**MORE CONTROL - NO MORE COLD WATER**	
RADIO	Jul-16	**Need for analogue controls.** To play with any kind of acoustic output, elephant would need a large degree of control, not just on/off switch. Analogue would be good for testing – chance to tinker with pitch, timbre, volume?	Touch - capacitance	**Some elephants like audio.** Demonstrates the individuality of the animals - why should we be surprised? Humans all enjoy different types of experiences. Another explanation might be that African males like radios but Asian females don't...? Points to the need for more tests with variety of elephants.	**Animal behaviourists don't always know the answers.** Lisa and Ashley didn't know what sounds they wanted to test either – so the experiment hadn't really been thought through carefully enough before we started. My interest in acoustic enrichment means that I have to ***investigate this topic independently.***
		Too much tech - capacitance touch shield + Audio FX soundboard + datalogger - Arduino Uno doesn't have enough suitable pins for all the inputs and outputs. Find a simpler way to synthesise audio instead of using samples that require memory and media player.			**Need for technical support.** It would have been great to have had a technical team as well as animal experts involved in the project. I will try to reach out to colleagues who have appropriate skills.
CONCLUDE		**ANALOGUE CONTROLS / SYNTH**		**INDIVIDUALITY**	**CASS WORKS / EXPLORE ACOUSTICS**

Too much hardware involved – too many things to go wrong. In the end we couldn't use the TR1220 datalogging shield because stacking shields is tricky – the pins are pre-mapped and sometimes the shields are trying to share specific pins which won't work.

We moved on to **sound synthesis** at this stage, because there might be the option to modulate the sound dynamically (with analogue controls) and also because it was impossible to second-guess what man-made (or animal) sounds would appeal to an elephant. There was no clear starting point. Various sound libraries have been developed for different systems to use for sound synthesis and we started to explore these. Dale Purves' work "Music as Biology" was influential as it explained why so many animals fail to respond to music – whereas listening to music is an experience that humans find evocative and emotional…

https://www.coursera.org/learn/music-as-biology
Why humans like music – potentially offers insight into what kinds of sounds other animals might find pleasing or interesting.



2017 - 2019: SYNTHESIS

BLOG POST: 14 March 2018
I've been working with BBC Micro:bits a lot in my classes recently, finding that they are more accessible than Arduinos for some of my students (those who are not programmers). As I hope to offer instructions for building acoustic / playful devices (so any interested elephant keepers can try out the designs), I thought Micro:bit tech might be the way to go.

Micro:bit has an onboard Accelerometer, which can be mapped to acoustic output that the board generates, using MicroPython music libraries. A free-moving object could contain the Micro:bit, powered by batteries, with amplifier and speaker, so that rocking or rolling the object caused different sounds to be generated.

The beam-breaker I tested last summer with my terrier could be scaled up and used as the input sensor in an elephant-oriented device, again using MicroPython music or speech libraries. In order to offer a range of outputs, we would need a range of beambreakers - either as individual inputs or placed in a sequence.

Early tests with Micro:bit speech synthesis for a beam-breaker button – tested with a dog – leading to further tests with MicroPython audio libraries…

MEDIA LINKS
- Micro:bit speech synthesis samples: https://soundcloud.com/user-607238008/microbit-python-speech-synthesis
- Micro:bit accelerometer mapped to acoustic output: https://vimeo.com/366066693

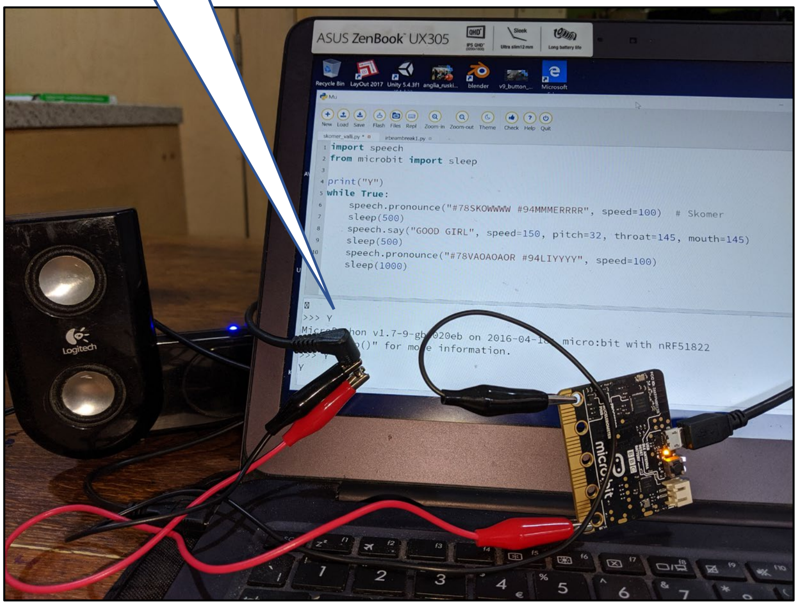
Keeper synthesis

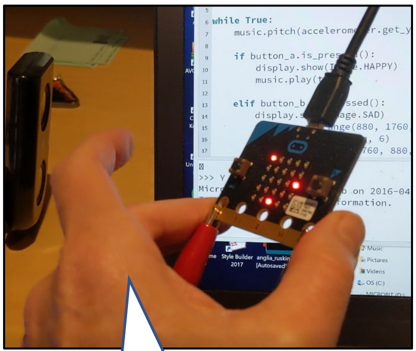
```
import speech
from microbit import sleep

print("Y")
while True:
    speech.pronounce("#78SKOWWWW #94MMMERRRR", speed=100)  # Skomer
    sleep(500)
    speech.say("GOOD GIRL", speed=150, pitch=32, throat=145, mouth=145)
    sleep(500)
    speech.pronounce("#78VAOAOAOR #94LIYYYY", speed=100)
    sleep(1000)
```

Screenshot from Python speech synthesis code

Micro:bit signal outputs directly to speaker input

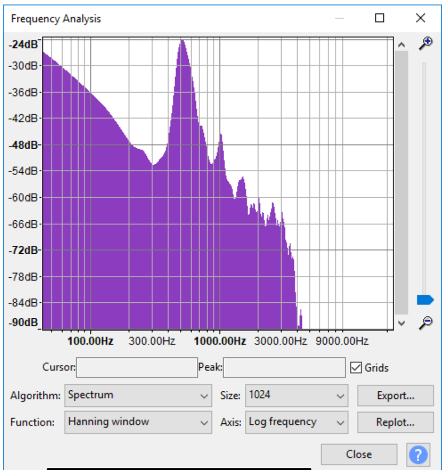




Tilting the Micro:bit

If humans love music because the melodies and harmonies we create derive from the fundamental frequencies found in human voices, as suggested by Dale Purves, then perhaps we should attempt to analyse the frequencies found in elephant voices in order to offer them sounds that are musical to their ears… But it's not as easy as it sounds…

2017 - 2019: SYNTHESIS

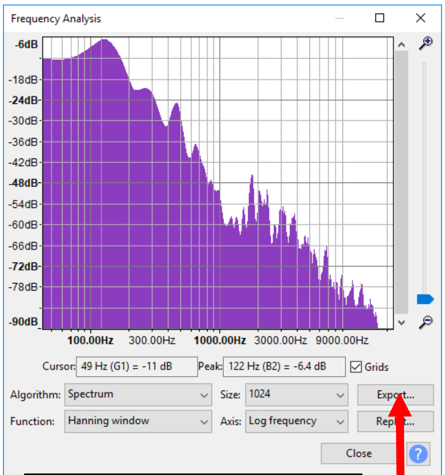


Asian elephant chirp

BLOG POST: 23 Jan 2019
So, I've been looking into additive synthesis, to see if it's possible to create elephantish noises programmatically. Not so simple. I considered procedural audio generation using [SuperCollider], but since [Processing] is designed to work with Arduino, picking up data via the serial port, it seemed a good idea to play with that first instead...

Processing has a new Sound library that enables synthesis of varous waveforms, and also additive playback. The video shows a few experiments. I loaded an African female elephant rumble and ran the FFT (Fast Fourier Transform) sketch to have a look at the overall shape of the sound. Good to see in real time, but [Audacity] provides a much better spectrum analysis that averages over a short clip. It's possible to capture the exact frequency of each of the peaks in the wave.

Other tests involved (i) loading an elephant sample (from [Elephant Voices]) and messing with the frequency and volume in real time using the Processing runtime interface - the basis for an interactive theraminey thing? - (ii) playing with additive wave generation and (iii) attempting to generate a digeridoo-type sound - not at all successfully!

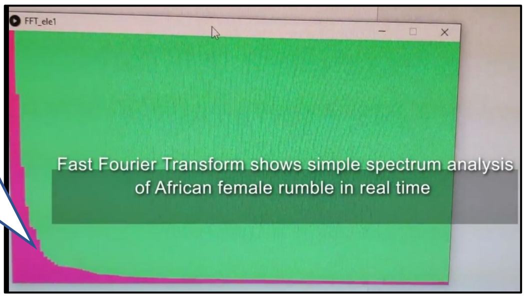


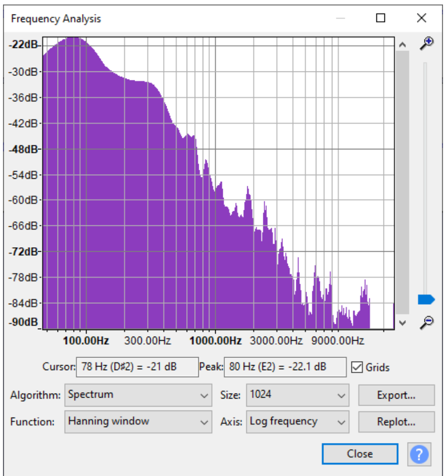
African female rumble-roar

MEDIA LINKS
- Processing audio experiments: https://vimeo.com/365647125

Notice similarity in shape (showing component frequencies at different volumes) – didgeridoo and elephant rumble…

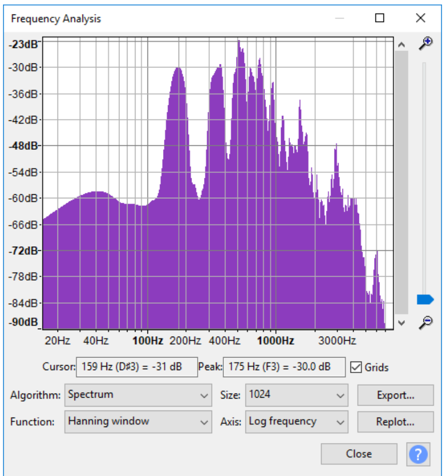
Experiments with Processing
FFT elephant rumble video still





Didgeridoo sample

Screenshots of frequency spectra produced in Audacity



Human female (saying "hello")

2017 - 2019: SYNTHESIS

DEVICE	Date	INSIGHTS Testing - tech - outputs	Input	Elephants - reactions to output	People
START		ANALOGUE CONTROLS		INDIVIDUALITY	CASS WORKS / EXPLORE ACOUSTICS
SYNTHESIS - MICROPYTHON	Mar-18	**Battery problems.** No mains lead for Micro:bit so relies on cells, which predictably run out too soon. Extra work for keepers and no good if system unexpectedly fails. Arduino can plug into mains – try instead?	Beam-break	**Robotic.** Acoustic output not of interest to dog … but Python libs able to generate interesting outputs. Doesn't sound very realistic… More experimentation required with different audio libraries - Processing has some new audio functionality.	**Sharing how-to.** Micro:bit is simple to use so would be useful and cheap kit to include in an Instructable – we want to share/disseminate ideas.
CONCLUDE		BACK TO ARDUINO		PROCESSING	

DEVICE	Date	INSIGHTS Testing - tech - outputs	Input	Elephants - reactions to output	People
START		BACK TO ARDUINO		PROCESSING	
SYNTHESIS - PROCESSING	Jan-19	**Processing.** Runs on PC – some great effects but need to check if delay between receiving signal from microcontroller and making sound. Arduino and Micro:bit have own audio libraries that can output signals directly to an amp/speaker – check Mozzi for Arduino.	NONE	**Modify samples.** Messing with elephant rumble sample was quite effective – try same with didgi and elephant controls?	**Music as Biology.** It's hard to synthesise animal calls and non-standard instruments (didgeridoo). Requires audio specialist as part of the team! We'll have to simplify this and research how others have accomplished similar tasks. Ask if colleagues interested in helping….
				Spectrum analysis. Useful to compare FFT in real time and snapshot of shape of the different sounds, made by elephants and created digitally.	
CONCLUDE		MOZZI		EXPERIMENT WITH AUDIO	EXPERT SUPPORT

Since we started experimenting with synthesis, a new library has become available for Arduino – **Mozzi**. So that's what we look at next, as well as finding a way to modify the audio output signal using an **analogue control**.

Cosmo Sheldrake samples the real animal and incorporates into music for humans:
- https://www.m-magazine.co.uk/features/interviews/interview-cosmo-sheldrake/
- Interspecies Collaboration: https://www.youtube.com/watch?v=NM80Y3cq_Vk

2020: SYNTHESIS

Mozzi

audio synthesis library
for Arduino
https://sensorium.github.io/Mozzi/

Since we started experimenting with synthesis, a new library has become available for Arduino – Mozzi. So that's what we look at next, as well as finding a way to modify the audio output signal using an analogue control.

ARDUINO CODE SNIPPETS

Setting up the ultra-sonic sensor and Mozzi library with oscillators

```
sonic_feb26 §
const int trigPin = 11;  // sensor sends signal
const int echoPin = 12;  // sensor receives signal after it bounces off surface
float duration1, distance1, d1, reading;

#include <MozziGuts.h>           // Mozzi library
#include <Oscil.h>               // oscillator
#include <tables/cos2048_int8.h> // table for Oscils to play
#include <AutoMap.h>             // map unpredictable inputs to range

// set limits to frequency and volume
const int MIN_CARRIER_FREQ = 22;
const int MAX_CARRIER_FREQ = 440;
const int MIN_INTENSITY = 700;
const int MAX_INTENSITY = 10;

AutoMap kMapCarrierFreq(0,1023,MIN_CARRIER_FREQ,MAX_CARRIER_FREQ);
AutoMap kMapIntensity(0,1023,MIN_INTENSITY,MAX_INTENSITY);

Oscil<COS2048_NUM_CELLS, AUDIO_RATE> aCarrier(COS2048_DATA);
Oscil<COS2048_NUM_CELLS, AUDIO_RATE> aModulator(COS2048_DATA);

int mod_ratio = 3; // harmonics
long fm_intensity; // carries control info from updateControl() to updateAudio()

void setup()
{
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  Serial.begin(115200);
  startMozzi();
}
```

Sensor sends a pulse and captures how long it takes to receive the pulse back after it bounces off an object directly ahead. This is converted to a distance, which in turn is mapped to both frequency and intensity (volume). If the slider knob is at bottom of scale, there is no sound (this is the default position).

```
void updateControl()

  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);          // send a pulse
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  duration1 = pulseIn(echoPin, HIGH);   // how much time to bounce back
  distance1 = (duration1*.0343)/2;      // therefore how far away

  if(distance1 < 20)  d1 = int(distance1);
  else   d1 =  0;

  // read the slider
  int slider_value = mozziAnalogRead(distance1); // value is 0-1023
  // map the slider to carrier frequency
  int carrier_freq = kMapCarrierFreq(slider_value);
  //calculate the modulation frequency to stay in ratio
  int mod_freq = carrier_freq * mod_ratio;
  // set the FM oscillator frequencies to the calculated values
  aCarrier.setFreq(carrier_freq);
  aModulator.setFreq(mod_freq);
```

It was critical to work alongside Chris, our technical support person – calibration and position of sensors within the device as well as appropriate fixings. I have intimate knowledge of the environment at Skanda Vale, which needs to be articulated, can't be shared so easily with a diagram.

This project highlights the value of working with professional craftspeople.

MEDIA LINKS

- Testing slider1 audio output
  https://vimeo.com/406357650
- Slider 3 audio output:
  https://soundcloud.com/user-607238008/slider-test-audio

Output: Acoustic

2020: SYNTHESIS

DEVICE	Date	INSIGHTS Testing - tech - outputs	Input	Elephants - reactions to output	People
START		MOZZI		EXPERIMENT WITH AUDIO	EXPERT SUPPORT
SYNTHESIS - MOZZI	Feb-20	**Volume control successful.** Able to map slider position to acoustic output, producing an oscillating wave that varied in volume, increasing from zero as the slider was moved upwards.	Slider	**Interesting output** using Arduino Mozzi library, works in situ with laptop.	**Over-reliance on my laptop.** Audio generated exclusively by my laptop, which means we can't leave devices in place for long period. We still need a separate audio source for longterm installation (not laptop).
		Digital output. Of course, it's hard to know what an elephant would think of this output, but it's more complex and unpredictable than a sine wave.		**Slider works in principle.** Elephants able to trigger audio, although it was a surprise for them.	
CONCLUDE		CONTROL ONE PARAMETER / WE CAN SYNTHESISE AUDIO		MOZZI	

Being able to leave the device in place while we were all away was important for being able to gauge elephant interest. Although the physical interface prototypes have a long life on the balcony fence, the embedded electronic aspects – sensors and outputs – require a stable power supply and a range of associated technical gear – microcontroller, wires, playback mechanism, amplifier, speakers etc. This typically means that when the researcher departs, so does the functionality.

We've established that the elephants still engage with the objects we left behind – it would be interesting to find out how they react to working toys/instruments if they were in place for several months. However, the infrastructure of a typical elephant shed makes this a difficult challenge, since there are few electrical sources and certainly not within easy trunk-reach.

There are many more interesting ideas to explore. Recent experiments with bone-conducting transducers may have potential, but would need to be sensed through feet, the same route as infrasound, rather than the soft flesh of trunks, which have no bones (all muscles). Merging signals – acoustic and tactile – seems as if we've travelled a full circle here.

Valli and Lakshmi's interest in large moveable items points to the possibility for analogue sounds (percussive).

Another lovely idea would be to use electronics to trigger natural sounds – this **CYCLOPHONE** at EMF (Electro Magnetic Field) 2018 uses a Dyson vacuum cleaner (blowing instead of sucking) to generate resonating columns of air in the pipes. Player must use a keypad to release valve at base of pipe so that air flows and note is made. Awesome build.

Keep listening folks!

5.7 Summary

Our fieldwork has enabled us to investigate the design of playful technologies that offer sensory and cognitive enrichment to captive elephants. Essentially, we wanted to identify suitable enrichment goals, to discover what might motivate an elephant to engage with a high-tech system that delivered these goals, and to explore the physical properties of such a system.

As we have previously explained, early ideas were generated after undertaking research to understand elephants as potential users of interactive technology and as animals who (in a captive environment) might benefit from novel environmental enrichment opportunities. We assessed our initial ideas for feasibility and discussed them with animal experts. Our early insights gained during the initial brainstorming period (See *Workbook – Ideation and Production*)*,* provided us with a useful framework for future designs, expressed in *Workbook – Ideation and Production: Framework for Design and Craft*. This highlighted key topics for consideration: technology, feasibility, modality, design principles, context, interactivity, collaboration and understanding other. The subsequent crafting and iterating period tended to draw out issues associated specifically with elephants; these have been collected in *Workbook – Ideation and Production: Application of Design and Craft*.

After the initial period of brainstorming ideas, we focused on developing concepts that mapped to both keeper interests and our own scope for research. By taking part in a *ZooJam* workshop, we were able to validate some of our ideas with colleagues and discuss new perspectives on the challenge; by using a *Research through Design and Craft* approach, we were able to project our thoughts into reality and test some of those concepts. Much of the early crafting was focused on inventing appropriate interface designs that enabled us to capture elephant inputs. Suitable outputs continued to be an interesting challenge, and we tried to generate novel concepts that would have elephant appeal.

Our ethnographic studies confirmed that elephants have different personalities and individual preferences, yet we managed to create some interactive devices that were usable and seemed to have appeal for different animals – male and female, African and Indian, protected and free contact, in herd-like social structures and alone. Our prototypes were opportunistic, rather than finished products, and they were used to give direction to and shape our ideas. This is how we have addressed our initial research question:

Will captive elephants engage with playful technologies designed to enrich their daily experience?

The answer is – it depends!

What it depends on is discussed in the next chapter: *Reflections on Design and Craft*.

Reflections on Design and Craft

This chapter reflects on the fieldwork undertaken during the ideation and production stage and offers an overview of technical and craft knowledge gained during the iterations of prototype design, development, and testing. Through these reflections, we address our two secondary research questions. In the following sections, (i) **Participatory Design with Humans**, (ii) **Interaction Design for Elephants**, and (iii) **Craft as Mediation**, we discuss the key areas highlighted in the diagram Application of Design and Craft in *Chapter 5: Design and Craft: Ideation and Production* (Design Principles, Collaboration, Understanding Other, Technology, Feasibility, Sensory Modality, Interactivity and Context). The final section, (iv) **Ethical Reflections**, shares some thoughts that have surfaced as we have worked on the project.

6.1 Participatory Design with Humans

The exploratory nature of our research meant that working with stakeholders was a critical part of the experience for us as designers. Stakeholders included zoo management staff, keepers, elephants, colleagues, and animal welfare specialists. In this section, we reflect on some of the collaborative relationships we built with humans; elephants are the focus of the subsequent section.

6.1.1 Working with animal experts and keepers

During the early ideation stage of the project, our discussions with EWG members, as well as other elephant experts, were invaluable for validating our ideas and offering us constructive criticism. However, one of the challenges we faced at the start of the development work was being able to make any *contact with elephant keepers* (and through them, their elephants) – they are all busy, committed people; looking after animals is an intensive, rewarding and skillful job. With regard to the provision of an interactive system for elephants, it was important to note the opinions of the keepers and how they would feel if the elephants were given more control over aspects of their environment, as well as whether there were any related issues. Although the keepers we met were without exception highly motivated to maintain and improve the welfare of the animals in their care, their interest in the animals' well-being had to be balanced against their other responsibilities and therefore there was rarely sufficient *opportunity to experiment with the unknown* – untested and unproved – types of enrichment we were hoping to trial.

Another feature of zoos that impacted on our ability to liaise effectively was their approach to research. Zoos are used to allowing zoology students access to undertake scientific projects, which typically follow a clear format. The exact nature of the intervention is known beforehand, whereas we were attempting to introduce a range of experimental and evolving prototypes. Although the enrichment goals were specified, we did not yet know the best way to achieve them. From most zoos, the same objections resurfaced – they wanted a finished version of the device, not a roughly-made prototype. They did not have time to work with us on concept development or manufacture. They rejected anything that impacted on their tight schedule or the schedule of the elephants or had the potential to change the animals' behaviour in a negative way. For example, Dublin Zoo were anxious about causing any kind of stress to their elephant calves because of the threat of EEHV (elephant endotheliotropic herpes virus) and this meant they were unwilling to trial any novel acoustic systems with the herd, because the stress value of novel items might make the calves more vulnerable. Noah's Ark insisted on deploying two identical systems inside the enclosure to avoid competition between their two bachelor males. Twycross staff informed us they would only test a stainless-steel version of an input device, not one made from wood, because they thought the elephants would immediately destroy it.

None-the-less, because of introductions made by Mark Kingston-Jones (working in an advisory capacity for the Elephant Welfare Group), we were fortunate to be able to work with Valli, whose keepers were very open to the idea of *optimistic inquiry with no fixed agenda* (a flexible trial and error approach with clear goals but no defined timeline for outputs – or in other words, having *opportunity to experiment with the unknown*). Because she was housed in a temple sanctuary (Skanda Vale Ashram) rather than a zoo, Valli had free contact (FC) with her keepers. This meant that she was used to regular interaction with humans, including handfeeding and washing experiences. Because she was used to responding to keeper requests and her actions were often directed by humans, it was difficult to draw significant conclusions by observing her in her usual environment, with keepers nearby. Her actions were likely to have been influenced by the keepers' presence. On the other hand, in this FC scenario, the keepers were more relaxed around the elephant, keen to help develop enrichment and full of ideas.

Collaborating with the keepers at Skanda Vale was an example of *participatory design,* as described by Lawson et al. (2016) and Jorgensen and Wirman (2016). It helped build good relationships and facilitated further interventions, while facilitating a *shared ownership* of the concept, which was motivating for everyone. Furthermore, the support of keepers was vital for the *deployment* of the devices, as we needed to access remote parts of the elephant shed and ensure that Valli was occupied elsewhere during the installation.

An additional benefit of having a strong researcher-keeper relationship was the continuing willingness of keepers to offer their own ideas for suitable and interesting designs. As a case in point, at Skanda Vale we initially found ourselves working simultaneously with two briefs (our ideas for playful systems and keeper requests for a shower control). We found that the tension between the two objectives altered the way we tackled the challenges. It transpired that the briefs were in fact complementary. Our broad aim relating to playful enrichment lent itself to a RtD approach, because we had no idea what kinds of systems might be interesting for an elephant, whereas the clear brief to develop an 'elephant shower button' required a more prosaic 'usability' approach that assessed the utility of various control systems. The outcome of using the shower device was predetermined. Yet, the open question regarding what elephants find interesting and pleasurable (for our playful system brief) led us to discover more about the elephant's responses to the shower design, and to modify both input and output - the interface, so that it was more aesthetically pleasing (of which more later), and the tactile quality of the water supplied (fine spray rather than jet). Thus, our *flexibility and readiness to compromise* in order to facilitate keepers' requests had a positive outcome on the project.

Our work at Noah's Ark Zoo, installing an 'elephant jukebox', highlighted another key issue associated with collaboration – the need to *keep devices simple* for other people to maintain. The electronics in the jukebox were complex, and, as mentioned in *Workbook: Input*, we had battery problems and needed to reset the system regularly. This was not work that we were expecting keepers to perform, and the example serves to illustrate another important aspect relating to collaborative work – KISS – '*keep it simple*, stupid'.

There is no doubt that this project would have been impossible without the continuing support and participation of willing elephant keepers. However, their enthusiasm and involvement also highlighted some issues we experienced regarding *experimental procedure*.

There was a strong assumption from many keepers and welfare experts that *food* should be the motivator for elephant enrichment because of the large proportion of time that wild elephants spend foraging. However, because an elephant is so motivated by food, using food as an initial motivator means that it then becomes impossible to determine if the animal is performing an action for any other reason apart from the possibility of a food outcome. Food is also strongly associated with training activities, whereas our aim was to design a system that invoked playful behaviour, and play is characterised by being voluntary, not trained (Brown, 2010; Sicart, 2014).

This came to light when we tested the pipe buttons with Valli (See *Workbook: Input*). In retrospect we realised that banana enticement was counter-productive with regard to assessing the viability of the interface design because Valli's focus was always on food. When bananas were removed from the situation, the problem was not only that the association had already been made, but also the fact that the residual chemical properties of the banana were easy for an elephant to smell. In subsequent trials, we discouraged Valli's keepers from inducing her to engage with a new device using any kind of food reward, although we were not always successful, partly because some keepers did not appreciate our concerns and partly because they found it difficult to change their usual mode of interaction with the elephant.

Even without the addition of food as a distraction, it was problematic to assess the effect of individual aspects of the design, because of the integration of so many modalities. Whereas humans may be relied upon to try and separate perceptions into different categories – visual, tactile, acoustic etc. – and can therefore tell a designer about their experiences with each sensory modality, we do not know whether animals can similarly distinguish between modalities, nor how they might be able to communicate their experiences with each sense. Moreover, it was difficult for us to gauge Valli's responses because of the conflation of the sound effects with other stimuli, such as the presence of strange human researchers, unusual smells emanating from a novel device and the recurring possibility of food rewards. In fact, our primary indication that a prototype might hold potential for a positive experience was whether the elephant voluntarily interacted with the device, particularly during periods of solitude or between feeding opportunities. Supported by the keepers' expertise, we understood this to mean that the object had some intrinsic appeal, inviting exploration because of sensory invocation or through cognitive stimulation or both. Working with the keepers and obtaining their feedback became a crucial part of our research as we fundamentally relied on their expertise when *evaluating prototypes* in the field. They were able to interpret the elephants' reactions to devices over a long period of time and share their knowledge with us.

Prototyping in the Noah's Ark environment resolved key questions relating to experimental procedure within a zoo setting, as well as raising issues that we had not encountered when working with a single elephant (dealt with in this chapter, *Section 6.2*: *Interaction Design for Elephants - Understanding Other*). The keepers at Noah's Ark and the EWG researchers emphasised that novel enrichment should be introduced to the elephants' enclosure and left for the animals to discover independently, in contrast to the keepers at Skanda Vale, who always personally introduced new systems to Valli. As mentioned above, the problem with the latter approach is that it may have set up some expectations – Valli might have behaved differently without keepers present; it is possible that she interacted with the buttons in the hope of receiving a reward or some positive encouragement, since her relationship with her keepers is very personal. Janu and Machanga (at Noah's Ark), on the other hand, have a protected contact relationship with their keepers, suggesting that they are less likely to seek approval. In any case, allowing the elephants to investigate novel features in their environment in their own time allowed us to confirm that they would be curious when they first noticed the devices through their visual perception. In contrast to Valli, they were both actively engaged with testing buttons for several minutes (until the system failed to work as expected).

We were fortunate that in 2018, Skanda Vale installed a surveillance system with 24h video footage capture, which proved invaluable in assessing interactions and discovering what the elephants (by this time, Valli had a companion) chose to do (with our prototypes) *without* the presence of human observers. The elephant keepers showed the author how to scan at speed and download footage from the system. During the following weeks, without being asked, they picked out relevant clips of elephants interacting with our devices and shared them with us.

The differences in procedure point to another discussion that is common amongst ACI practitioners – whether to opt for training (to use a new device) or self-discovery, whereby the animal finds out by herself how things work and what they do. The former method cuts straight to the chase, avoiding lengthy learning by trial and error in favour of enabling the animal to use the enrichment device quickly; the latter method typically takes longer, but arguably offers a greater sense of control over the experience and supports the confidence required to fully explore one's environment. We have heard strong arguments for both perspectives, but the key take-away from this is the need for *researchers to communicate well with keepers* so that understanding and agreement is reached.

6.1.2 Working with technical and academic experts

In addition to all the expert advice and support we received from elephant and animal welfare experts, we found it extremely helpful to work with technical colleagues who were able to offer rapid prototyping facilities and support. Although many of the prototypes were hand-crafted in our own workshop, making the final version of the slider also required specialist equipment and skills. We note that creating detailed blueprints for our technical colleagues was extremely useful, both to clarify the design from the designer perspective, and to enable another person to support the crafting of it.

We have also collaborated extensively with academic colleagues to write papers and facilitate workshops (such as the ZooJams) that discussed enrichment ideas. In papers relating to the elephant project, we documented the different stages of development, from concept work to physical prototypes, giving rationales for design decisions (see *Appendix A8: Publications*), with the goal of sharing ideas in the ACI community and beyond. Since the designs we produced will be improved upon by others, it has been important to disseminate the knowledge, data and skills acquired during the process. Therefore, we have also tried to engage with a range of people by deploying different platforms. The media outputs of the research are publicly available online in the form of a blog (toys4elephants), showing photos, sketches and diagrams, linking to relevant audio files and presenting a collection of videos on Vimeo (UX for Elephants) – see *Appendix A7: Media Links*.

6.1.3 Facilitating collaboration with a ZooJam

We have explained that designing and prototyping as part of an interdisciplinary team was a fundamental aspect of our work, and we therefore invested some time to explore new methods for facilitating creative and productive communication between distinct communities – the animal welfare experts and species specialists, and the interaction designers and technical developers.

We hypothesised that a *game jam* (see *Chapter 2: Background Research: Game and Design Methodologies – Game Design*) could be a useful vehicle for developing new ideas – specifically new ideas relating to the promotion of animal welfare by encouraging the expression of natural behaviours through artificial means. We therefore instigated a new form of game jam – a *ZooJam* – whose format illustrated how games for non-human animals could target species-specific environmental enrichment goals. The aims were twofold: (i) to *bring together colleagues from a range of disciplines*, all focused on developing practical solutions to different environmental enrichment challenges; (ii) to *extend the reach of UX design beyond human experience* in order to become inclusive of other species and their interactions with technology.

The ZooJam concept was inspired by the experience of organising and participating in game jams, where the output is focused and design-complete – participants are required to design and develop a game within a limited timeframe. In jams such as GGJ (Global Game Jam) and Brains Eden (Brains Eden Game Jam), teams rise to the challenge of working together to meet a specific brief. Creative exploration is a highlight of the experience and there is a strong sense of achievement at the end, with a tangible product, albeit in a prototype state. Many jammers (game jam participants) continue to refine their games after the event.

We wanted our workshop participants to have a similar experience during the ZooJam events, so it was important to structure the sessions to facilitate *creative expression*, *skills-sharing* and *goal-oriented outcomes*. However, instead of making a game, the focus would be on finding a playful solution to an enrichment goal provided by an animal welfare specialist. Previous attempts to use a game jam format to stimulate ideas for enrichment include “Orangujam”, devised by Wirman

(Orangujam, 2013), and “Design Challenges with Ants” by Westerlaken and Gualeni (2016). These jams, aimed at enrichment for orangutans and ants respectively, were successful in that they produced relevant concepts which were then developed and tested.

The three ZooJam events we developed and held 2016-2018 were formatted differently from the Ant and Orangutan jams; for example, each ZooJam focused on a theme, rather than a specific species. Within each theme, scenarios were described in detail via briefs given to participants by animal welfare experts. The organizing committees for each event comprised experts in animal behaviour, technology, design and animal-computer interaction. We found that this represented a useful mix of skills, in that different specialists were able to raise awareness of species-specific needs and the opportunities afforded by technology. Similarly, at every event the participants were diverse, including animal professionals (zookeepers, representatives from the RSPCA (rspca.org.uk, 2020) and from Shape of Enrichment (SHAPE), dog trainers, animal welfare experts), technologists (engineers, computer scientists, networking professionals, game developers), UX designers and ACI practitioners.

It was important that the ZooJam would produce *useful* outcomes – meaning that colleagues who worked professionally with animals would be able to leave with appropriate, practical solutions for their enrichment goals, while ACI colleagues with computing backgrounds would gain deeper understanding of their potential users. Consequently, to ensure that the design experience was grounded in real-life challenges, we asked participants who were animal experts to offer us *briefs* for the events. The briefs were succinct – each defined an *enrichment goal for a specific animal* and described or depicted the typical environmental context for that species in its captive context.

Each year, the ZooJam explored a different *theme*. In 2016, the inaugural ZooJam responded to briefs that required hunting behaviour to be stimulated in specific zoo-housed animals – sea lions, penguins and big cats (French et al., 2016). In 2017, the FarmJam focused on environmental enrichment for intensively farmed animals – pigs, goats and chickens – and the associated challenges (French et al., 2017). In 2018, the SoundJam addressed opportunities for auditory enrichment for animals in a range of captive contexts – chimpanzees, parrots, servals and *elephants* (French et al., 2018). Every new enrichment goal became an unsolved problem waiting for colleagues to brainstorm ideas and develop solutions. As facilitators, we used the jam themes to guide jammers’ creative outputs. However, in keeping with the tradition of game jams, we withheld these briefs from participants until the event took place. One of the reasons for this was so that participants could engage spontaneously with the briefs during the brainstorming stage, working with fellow team members. Had people known too much information in advance, there would have been a temptation to come with pre-formed concepts; the jam would have then become a forum for exchanging existing ideas, rather than a platform for fluid and evolving collaborative engagement. We hoped that participants would be inspired and provoked by each other's creative outputs, would listen and be responsive 'in the moment', thereby immersing themselves in the experience of the game jam. Similarly, we hoped to collect outputs that were generated during the event, rather than compile a set of contributions that were determined beforehand.

After the briefs were explained to the participants by the animal experts, the next stage for all jammers was to *brainstorm* as many ideas as possible for each brief. The animal experts were involved in this process as game jam participants, and we pre-selected groups so that people with different skills and knowledge were mixed as much as possible. There was time to *network and reflect and make contributions*, but the sessions were tightly managed so that people were required to *focus* on their tasks.

The subsequent stage involved sharing the concepts with the larger group. In order to present ideas to colleagues at the ZooJam, teams spontaneously used sketching and/or modelling – making very rough designs in order to communicate their thoughts more easily. We supplied a range of materials to facilitate this process. Key to this stage of the workshop was the *imprecise and incomplete* nature of the ideas, emphasizing that they were questions opening a discourse with other participants; no-one in the room knew the "correct" answers but we were all motivated to *explore possibilities*. At this stage, concepts could easily be adapted so that people could invest their own creativity into the designs, enhancing and refining them. The animal experts who provided the original pitches each moderated a short session during which ideas were presented, thus facilitating a *filtering process* based on early feedback.

After a break, participants were encouraged to *re-form teams* based on the animal enrichment device that they were most interested in developing to a *higher level of detail*. Teams were under pressure to develop an idea with the potential to be successful as a future full-size prototype and research project, and the *limited time factor* was a motivator that also aided clarity of thought. It is a common experience of jammers that they can achieve tremendous creative outputs in a concentrated period of time, because they are working with no distractions in a supportive atmosphere with other focused people (Kultima, 2015). A key aspect of this part of the jam was the opportunity to co-create using physical materials (*co-crafting*), a topic we discuss in detail in the next section.

We asked participants to present their final designs using graphical and physical representations as well as verbal descriptions. The platform for presentation emphasised *clarity, economy, level of detail* and *communication skills*, additionally providing an opportunity to answer questions. In a ZooJam, the output was a clearly defined blueprint or design for a prototype device. This is similar to a game creation challenge, in that the specifics of interactivity and functionality (gameplay) have to be clarified and explained, as well as the aesthetics of the artifact (see *Aesthetics for Elephants*).

Some ZooJam outputs used the technology to *simulate* conditions as they would be in the wild – a Wizard of Oz approach so the animal had no knowledge of unusual interventions. Others used the technology more explicitly, as an *enabler*, giving the animals some choices and control over aspects of their environment. In many cases, *tracking* was also identified as a possible additional benefit of using technology. Interestingly, when small teams were faced with the same brief, yet worked independently, they regularly came up with both unique solutions and similar solutions - the same ideas occurring spontaneously within different groups. How can we interpret this? It might be that the best solutions are the ones that most people have converged on - or it might be that these are in fact the most *anthropocentric* solutions and we are all drawn inexorably towards them because of our human experiences. As an example, in regard to the elephant brief (in *Workbook: Ideation and Production - ZooJam*), some of the concepts that emerged were similar to ones we had considered ourselves during our early ideation period. We felt that this validated our creative work, since other ACI designers and animal experts came up with similar ideas to our own. Moreover, it was helpful to obtain different perspectives on the challenge of designing an interesting artifact for an elephant.

Moreover, regardless of participants' backgrounds, we found that learning to appreciate some of the motivations and unique behavioural characteristics of non-human animals could offer fresh insights into how different users might benefit from novel designs - for example, some of the bubble toys aimed specifically at Magellanic penguins (zoojam.org/hunting) would not be out of place in a large leisure pool during the school holidays. It was good to hear that Michelle Westerlaken, who provided the original penguin brief, subsequently organized *design and craft* sessions with her interaction design students at Malmö University. (michellwesterlaken.com, 2016)

6.1.4 Wrapping up

Working with keepers was a key aspect of our work, which we continue to discuss in the next section, *Interaction Design for Elephants*. In this section, we have reflected on the value of participatory design for *shared ownership* of a concept and for helping to build good relationships between keepers and researchers. We suggest that it is the responsibility of the interaction designer to *Keep It Simple* so that all stakeholders can appreciate the design and feel able to contribute; demonstrating flexibility and a willingness to *compromise* is also conducive to building mutual trust. Good relationships imply *good communication*, which additionally facilitates procedural aspects of the project, such as when and where to install prototypes.

Based on our experiences, we found the *ZooJam* format to be very successful in meeting its aims of engaging a range of participants from different disciplines and enabling them to explore possibilities for novel kinds of environmental enrichment. We would like to draw particular attention to the co-crafting aspect of the jam. As well as supporting collaborative practice, we believe this activity helped participants raise their personal awareness of the non-human target users.

We therefore recommend holding a ZooJam to support concept development at the start of an ACI project, partly addressing our third question: '**What design methodologies would best enable designers to identify and develop the most appropriate designs for such (playful enrichment) technologies?**' In the following section, we elaborate on designs and address our second question as we consider the stage of the project that involved the production and testing of devices.

6.2 Interaction Design for Elephants

We have explained how important it was for us to be able to work with elephants and their keepers, firstly to share and develop concepts with the professionals looking after the animals, and secondly, so that we could try out our ideas 'made real' – it was critical to try and gain an understanding of the elephant's perspective on a novel device, but also quite tricky: how could we imagine what they were really thinking? In this section, we describe some of the design principles that emerged as we progressed and explain our insights regarding form and functionality.

This topic is divided into the following sub-sections: (i) Design values; (ii) Control features; (iii) Differentiation, Consistency, Graduation, Specificity, Multiplicity and Affordance; (iv) Understanding other; (v) Aesthetics for elephants; (vi) Auditory and tactile aesthetics; (vii) Performative aesthetics.

6.2.1 Design values

At the start of the project, to contextualize our work in the contemporary environmental and cultural climate, we ascribed to design values that we felt would be supportive of both sustainable development and environmental ethics. These values are consistent with the aim of designing technology for animals who are often kept in captivity for conservation purposes due to the environmental degradation and habitat loss that is now threatening many species' survival. They are also consistent with the aim of sharing our work with the wider community, to help propagate its underpinning values.

We established some key principles at the start that embody these values and ethics. They have underpinned all our subsequent development work. In particular, we wanted our designs to be *eco-friendly* and *open source*. Thus, we always attempted to *recycle* found objects, such as drainpipes, ropes and plastic buckets; we used off-cuts of wood to *reduce* waste; we repurposed existing mechanisms in order to *reuse* objects. In addition, since we wanted to share projects with the wider community, thus enabling greater collaboration, our designs' embedded inspired by an open-source philosophy and we used free software and development environments such as Arduino (2020), Audacity (2020), MicroPython (2020).

Our research and development then highlighted the need for other key principles that related specifically to the design of objects for animals. For example, we attempted to craft most of the prototypes from materials that would be encountered *naturally* by a wild elephant, such as wood and plant-based textiles, although we also experimented with manmade resources.

In addition to these design principles, which were associated with our approach to the challenge and with the physical properties of the artifacts, we ascribed to another important principle relating to animal welfare. After attending a short course on environmental enrichment, run by SHAPE of Enrichment (SHAPE), we understood that any intervention requires a *clear enrichment goal*, which needs to be articulated to the animal carers to clarify the purpose of the research. Taking the course enabled us to speak with confidence to a growing network of keepers and animal welfare experts, which facilitated our aim of working with elephants. Our enrichment goals were to provide *cognitive and sensory stimulation*, with an early emphasis on the provision of *controls for acoustic outputs*. Consequently, moving forward with ideas, we began to focus on interface designs that would be suitable for elephants to use.

6.2.2 Control features

We started with the simplest idea – a binary ON/OFF control that would trigger either a sound (as per our research agenda) or a shower (as per elephant keepers' preference). Yet the functionality of the design soon raised tricky questions regarding system status – does the button remain 'ON' after triggering, or does it revert to 'OFF' as soon as the interaction stops? If it remains ON, how does the animal change the status? Using the same button? How does the animal know whether the button is currently ON or OFF? Does the button itself offer some indication of its status? Would this not require the interaction design of the device offering feedback that was distinct from the output that it triggered?

Solutions proposed by animal experts included using beam-break technology, which meant that moving an object (trunk or ear or stick) across the IR beam would trigger the control. But we realised that if the control automatically reset after the object was removed, this could be very frustrating: imagine a touch shower control that you can activate with your hand and then as soon as you try to pick up the soap, it switches off again; or imagine a music player that only plays while you keep your finger on the button. This problem suggested that the button should remain in an ON state, yet that could also be frustrating if the user did not know how to switch it off.

We experimented with buttons that offered acoustic and haptic feedback when activated, but which were in fact designed to control other outputs. Having observed Valli using these buttons, we concluded that the mapping of the button feedback and the associated output would be difficult for an elephant to comprehend, since feedback (e.g. vibration) and output (e.g. water) were both immediate but the output was located remotely from the device. With the water controls, we needed to physically separate the electronics of the button from the output of the system, for obvious safety reasons.

In the end, we developed systems with a timed output; after triggering the device (which had no inbuilt feedback mechanism), the output continued for a short time (several seconds) and then switched itself off. While it was ON, the button did not function, but became usable again when the output had stopped. As examples of this, our shower controls activated a water supply for a ten second period and our elephant radio triggered playback of short samples that (by definition) had a temporal quality. In both cases, the elephant did not need to keep his or her trunk on the button to experience the output.

However, one simple binary on/off button offers limited potential for exploring preferences, other than whether to activate a system or not. Additionally, our design meant that the elephant lost control after triggering the output, whether audio or water, because it continued for a fixed duration whether she liked it or not. Personal human showers, on the other hand, usually have knobs that can be turned, enabling a graduated response from the system (from hot to cold, from forceful to dribble); generally, only public changing rooms use an automated approach. We were committed to offering an elephant more choice and control of the situation, which meant offering more buttons that triggered different events. This led us to some other important facets of design, explored below.

6.2.3 Differentiation, Consistency, Graduation, Specificity, Multiplicity and Affordance

Elephants needed to be able to *distinguish between* different controls if there was more than one. This also raised some interesting questions. If we supplied a series of buttons vertically (which would fit better on Valli's balcony rail), would the elephant perceive a hierarchy? Browsing holes in zoos are often intentionally situated at different heights to allow all animals of different sizes to have easy access (see Figure 28: Hierarchy). Does this imply that the higher buttons are for more mature (and therefore probably higher in the hierarchy) members of the herd? In other words, would we be 'loading' the top buttons with elephant prestige? On the other hand, if buttons were laid out horizontally, might that be confusing? Would an elephant recall which button performed which task? We just do not know how elephants interpret these kinds of features. It would be possible to use other kinds of differentiation, such as shape, size, colour, texture etc. But there is another facet of design that also needs to be considered – *consistency*. This is one of the key interaction design principles identified by Norman (2013), whose work is widely accepted as being seminal in the field of Human Computer Interaction (HCI).

For our elephant controls to be consistent, we established that there were three criteria to consider. The first two had direct benefits for the elephant user: (i) *technical competence* – controls had to be reliable and produce the *expected* results every time; (ii) *offering learned affordance* – encountering the same design again should reveal to the elephant *what to expect* when using a control. The third criterion supported designer evaluation: (iii) *undifferentiated except for specific functionality* – buttons had to be sufficiently *similar* such that any selection on the part of the animal could be interpreted as a choice of output, rather than a choice of button features (e.g. texture, shape). In other words, we wanted the controls to capture the animal's *deliberate intention*.

Figure 28: Hierarchy

Thus, if we offered three buttons that would permit a choice of acoustic output, it was important for our test procedure that despite being spatially diverse, those buttons offered the same *sensory* stimulation as each other – except for the sound that they triggered. In time, we came to regard this feature as critical and distinct from consistency; as an interaction design principle, we referred to it initially as *singularity*, then changed this to *specificity*, which seemed to be a better choice of word for the design principle we were describing.

The second feature of consistency – learned affordance – clearly relates to Norman's design principle of affordance, as referenced earlier in *Section 5.2 Elephant Requirements*. The term originated with Gibson (1977), who described affordances as '*action possibilities*' in the world. His early work on the topic related affordances to the experiences of all animals in their respective environments; later, the term gained traction within the HCI community when it was applied to designs for humans. More recently, the idea of affordance has been broken down into *signifiers* that offer (usually visual) cues to interaction possibilities (Norman, 2008) and *feedforward* (Vermeulen et al., 2013) which is an understanding of what will happen when an interaction takes place. Together these provide the user with a mental model that enables them to control the system, but this knowledge sometimes only comes with experience and is a hallmark of *accomplishment* (Gibson & Pick, 2000). Gaining control and competence through practice closely maps to the idea of learned affordance. Thus, in common with ACI research by Mancini et al. on interaction design (2016), we concluded that *affordance* was an important design principle when designing with and for animals. Offering them a system with controls that can be activated using a familiar mechanism supports their cognitive capability. For example, a rope invites itself to be tugged by an elephant, who is accustomed to tugging on thin branches, while a small moving ball may attract a cat to pounce on it and a perch will seem an obvious place to settle for a parrot. The rope, the ball and the perch could all be transformed into input controls using different kinds of sensors.

In total, Mancini et al. identified four design principles relevant for dogs: perceivability, consistency, feedback and affordance (2016). Norman's well-known and widely accepted design principles are visibility, feedback, constraints and mapping, as well as the afore-mentioned consistency and affordance (2013). In the context of ACI, although *visibility* can play an important role, sight is not necessarily the primary sense for perceiving the world, as it usually is for humans. We explore this topic in *Section 6.2.5 Aesthetics for Elephants*, essentially supporting Mancini et al.'s viewpoint that *perceivability* is a more appropriate term, since it encompasses more senses. *Feedback* is a principle shared by both sets of researchers, but as we explained in *6.2.2 Control features*, the overlap between feedback and output from the systems we designed make this a difficult characteristic to implement and monitor successfully. This problem is perhaps expressed through Norman's design principle *mapping*, which highlights the importance of a clear connection between a control and its effect, from the perspective of the user. To clarify, our use of the term *map* is more generic; for example, *map* is a specific programming function that is used to align two or more sets of values.

At this point in the discussion, we should note that our prototypes sometimes failed these important criteria (differentiation, consistency, specificity, affordance). As a case in point, some kinds of sensors proved to be unreliable in the field (e.g. capacitance sensors) and some kinds of outputs were hard to achieve (e.g. water pressure fluctuated, which spoiled our shower). Regarding affordance, we would not expect an elephant to be able to guess the function of a static button *the first time* she encountered such a device in the enclosure, but we would expect her to anticipate what might happen if she touched the same object (or a similar one) again. Indeed, this proved to be the case, as Valli refused to interact with a button that had previously triggered an unwelcome jet of cold water. We supposed that a similar object would elicit some recognition and recall, yet she was willing to try novel 'button' objects once more a few months later. Perhaps this speaks well of her confidence and curiosity, or perhaps she is an elephant who forgets... Finally, we must be clear that all tests with elephants were carried out inside elephant enclosures, which cannot provide laboratory conditions. Thus, it was impossible to ensure that each button in a collection would evoke the same sensory stimulus – elephants may have been able to distinguish between buttons due to their smells, for example.

Returning to the elephant radio example, we decided to create three identical (to a human's perception) buttons and set them horizontally, each one triggering a different pre-recorded audio sample. While this provided consistency in the design, we believed that it would be easy for an elephant to distinguish between three buttons, after a bit of practice. The challenge for our research, at this stage, was to discover a suitable acoustic output that would appeal to an elephant. We realized that in order to explore elephant preferences in this regard, we would need to offer controls that allowed them to modify the acoustic signal, rather than simply play one or another noise selected by a human. Hence, we needed to develop some kind of analogue input device, which could capture a graduated response from the elephant. This directed our attention to another facet of design – *graduation*.

There are many different ways that an elephant can interact with the world using her trunk, which has more degrees of freedom (to move) than a human arm (Walker et al., 1999), with a similar grasping potential at the tip. This wide range of movement can be exploited in the design of an interactive system, just as the range of possible modes of perception can be explored and utilized. We named this design feature *multiplicity*. However, in regard to the development of analogue controls, it was apparent that limiting the range of movement would make it both easier to measure, from the designer's perspective, and possibly easier to understand, from an elephant's perspective. Although Norman's design principle '*constraints*' is suggestive of such a limitation of movement, we felt *graduation* to be more fitting for our work, because constraints has wider implications. We discuss our attempts to implement a graduated control in *Section 6.2.7 Performative Aesthetics*.

We therefore found that the critical features that a system interface needed to be able communicate to its elephant users were *differentiation, consistency, specificity, affordance, graduation and multiplicity*. In our assessment, perceivability, feedback and affordance were all aspects that *enabled* the key control features we identified. As a result, we experimented with sensory parameters that supported these features in the use of static interface panels and moving control mechanisms that offered the experience of *performative aesthetics* (of which more later).

The starting point for our design work with elephants was the concept development we discussed in the previous *Collaboration with humans* section, but in fact it was during the *crafting* and *deployment* of devices that ideas really began to take shape, literally and figuratively. The main themes emerging from the craftwork related to the design of devices such that they appealed to our elephant users, and how to enable desirable features using existing available technology and resources. The next section explores some of the issues around designing with elephants in mind.

6.2.4 Understanding Other

When people work closely with domesticated animals, such as canine companions, a mutual understanding emerges because of the proximity between human and dog, and the requirement to observe/listen to/smell/feel each other in order to communicate. Sharing that world space and having mutual awareness gives each species some insight into the other (Haraway, 2008). However, this is unlikely to happen with undomesticated zoo-housed species, who are typically maintained in environments without human social contact – as we have discussed, keepers now aim for Protected Contact only in order to carry out routine tasks such as medical checks.

As well as experiencing the world at a different scale, often non-human animals rely heavily on different senses and certainly have a different set of common sense principles (e.g. if in doubt, climb a tree.) Other animals lack the exposure humans have had to computer systems and interactions with technology, even if the animals' abilities transcend our own in areas such as pheromone identification or balance. Moreover, physical capabilities such as strength and speed, and psychological motivations such as hunting and foraging may make a significant difference to how an animal perceives and interacts with the world.

For a UX designer working remotely, not in close daily contact with the user, it can be difficult to fully appreciate the qualities of the 'other' (user) that will help define the most appropriate way of designing an interface or system or experience. While this is true even of humans, who have variable characteristics and requirements within the same species, the dilemma becomes more critical when the user is a different species – in other words, when we are designing for an animal.

Human designers have no mental model of what life is truly like for a different species and the *physicality* of an animal is one aspect of their experience that we inevitably find hard to conceive. An example of this is that when working with Valli, we found ourselves imagining Valli's trunk to be a similar size to a human arm, because that was the most obvious articulated and living thing in the vicinity, was part of the designer's own body, and of course it also had useful digits at the end. Objects were constructed accordingly, and the primary researcher was constantly surprised on arrival at Skanda Vale to see the real size of Valli's appendage – which was of course much bigger. In fact, *dimension* (scale) became a major design challenge due to the geographical distance between the workshop and the elephant shed. Although we understood that the controls had to be an appropriate size for an elephant trunk tip to activate, it was difficult to fully appreciate the scale and strength of an elephant without being in close proximity. To resolve this issue, some rough measurements of Valli's trunk tip were made and we designed a *template* to work with, to ensure that the work was at the correct scale. At a later date, we repurposed an old oven glove (large and padded) so that a person testing a device could attempt to interact with a prototype interface using a larger, blunter instrument than a human finger.

An unconscious anthropomorphic tendency was for us to continually compare the trunk tip to a human hand. Martin and Niemitz (2003) found that Asian elephants are typically 'right-trunkers' or 'left-trunkers', which adds to the notion that the trunk can be compared in some ways with a hand – indeed, it is used for caressing, feeding oneself and others, investigating novel objects and manipulating tools. A trunk is also simultaneously a nose and a sound producing organ, which greatly increases its utility, but also complicates matters when we try to design an interface for an elephant to control a system. Foerder et al., (2011) comment that unsuccessful attempts to demonstrate tool use in elephants may be due to a misplaced emphasis on the trunk as a kind of 'hand' for holding a tool, whereas in fact it is primarily a sensory organ in the context of food. The repercussions of this are considered when we discuss aesthetics, later in this section.

Another important consideration for designers is the *context* in which the animals are maintained – for practical reasons, as we had to take account of the *particularity of the environment* as well as the animals themselves. This was critical in regard to deployment, as we had to agree with keepers where best to place devices and then be able to fix them securely to existing environmental features. We addressed this by conducting short (architectural type) surveys of the enclosures prior to starting any production work. Additionally, social contexts for captive elephants rarely replicate wild conditions and depend on the set-up in each institution. We therefore also had to try and appreciate our elephant users in their various environments, which meant understanding the *social dynamics* of the situation from an elephant perspective as well as considering practical aspects such as animal management and structure of enclosure. For example, a system could have been designed so that it required elephants to cooperate, but we did not know whether this would be beneficial, because captive animals have different backgrounds and different animals have different individual characteristics and temperaments.

Ros Clubb (*Appendix A3: EWG 2013*) strongly supported the idea of giving the elephants choice and control, and possibly making them work together to achieve a reward, to promote social cohesion. Oliver Burnham (*Appendix A3: EWG 2013*) warned that this might not work, if the elephants refused to take turns. '*Don't do something to cause competition*,' he advised, because often the dominant animal makes all the choices. As an example, Claire Bennett, Head Elephant Keeper at Colchester Zoo, commented that in a social/cooperative context, she believed that matriarch Tanya would coerce her companion Opal to undertake some work, but that Tanya would ultimately receive the reward. She also told us that none of the Colchester elephants were aggressive and that she did not foresee problems associated with competition, other than the inequalities mentioned above (dominant elephant takes the reward).

In our early design attempts with Valli, inter-elephant social dynamics were not a consideration as she was living as a single elephant until 2018. However, working with Noah's Ark was productive in that it brought to our attention some of the challenges inherent in designing an acoustic toy to be used by more than one animal. Our users were two protected contact male African elephants who were housed together, raising questions about competition for environmental resources. We addressed this issue by duplicating the system so that each elephant had individual access to the same device, while recognising that this was *not a scalable solution*. As explained earlier, we developed two sets of identical three-button systems, in which the buttons could be distinguished from each other by their relative positions on the wall – arranged horizontally. The two jukeboxes needed to be the same so the two male elephants in the enclosure both had something to play with and did not need to compete, so we ensured that each set of three buttons generated the same three audio outputs. Video recordings of the two protected contact elephants show that they were interested in the novel objects as soon as they noticed them. The older, larger male spent more time investigating the jukebox system; initially both elephants reached for the buttons, but the smaller elephant walked away. This raises questions for future research, relating to elephant *social dynamics*. For example, would it have made a difference to either elephant if the features were spaced further apart? How big is an elephant's personal space with regard to enrichment experiences? Would they take turns playing with a system? How likely would they be to share?

In many zoos, elephants are kept in larger groups and it would be impossible to provide individual elephants with their own personal jukeboxes. In addition, acoustic output has the property of being pervasive, which means that it would affect all elephants in the vicinity, not only the elephant who used the control. Mancini (2014) highlights this problem in a discussion of smart controls for dog kennels: '*For animals housed individually, smart controls seem practical, but for shared housing environments, there are challenges inherent in the design of a system that offers a personalised experience to one animal without imposing their choices on the other animals*.' Indeed, we have begun to appreciate the individual characteristics of elephants, who have different preferences and roles within the hierarchy of their herd, suggesting that no solution would be "one size fits all". McCormack et al (2016) support this notion with regard to enriching apes, who also exhibit individual characteristics. In other words, we should not expect enrichment to necessarily be identical for different elephants. This appreciation of individual preference led to a deeper investigation of the aesthetic aspects of the designed systems.

6.2.5 Aesthetics for elephants

While there has been significant research in Animal-Computer Interaction into interfaces for animals that are practical and usable, thus enabling interactions with computer-based systems, there has been less emphasis on the potential *pleasure* associated with the encounter (French et al., 2020). This is especially important for interactions whose purpose is to positively enrich the lives of prospective animal users.

It is evident that aesthetic sensibilities vary when we compare the activities of different animals. For example, Plotnik (2010) reports that, as a part of their self-maintenance and social bonding routines, chimps spend time grooming each other while elephants have mud-baths and spray dust on their bodies. In both cases, these activities enhance the health of the animals' skins while also providing significant tactile stimulation, but the chimps are removing dirt while the elephants are applying it. These differences in daily practices and aesthetic experiences influence the way in which different species respond to external stimuli, sometimes leading us to misinterpret their capabilities. For instance, the mirror recognition test, typically used to verify whether an animal is capable of self-awareness, involves painting a mark on an animal's face and checking to see if the animal touches the mark when they look at themselves in the mirror, implying that they recognize their own reflection. Plotnik's theory is that, given their grooming habits, chimps might be expected to notice a strange mark on their bodies; on the other hand, given their bathing habits, it is hardly surprising if elephants pay little attention to such a mark and, if they do not, it does not necessarily mean that elephants are any less self-aware than chimps.

As we have previously discussed (*Chapter 4: Understanding elephants*), research has shown that elephants' sight is relatively poor, while their olfactory and auditory senses are extremely sensitive. It therefore made sense to take the sensory abilities and associated interests of elephants into account when designing enrichment experiences for them. Moreover, we believed that the aesthetic dimensions of elephants' *sensory characteristics* had to be a central focus in order to fully engage the animals with any new system, with a particular emphasis on their most developed senses (predominantly their tactile, olfactory and auditory ones).

Every device we created had visual, olfactory, aural and tactile properties – each physical object within reach could be seen, smelled and touched, and in each case the feedback or output from the device had an audible aspect. Some of these features were specifically designed to be part of the system (for example, knitted textile interfaces); others were inevitable (for example, the scents added by humans manually crafting objects). We were careful to avoid using food as part of or as a reward for engaging with our systems, as we have previously explained – because we were keen that the devices should have intrinsic appeal and not be related to foraging behaviour or fitness. However, the sense of taste is closely related to the sense of smell and we were not able to judge whether chemical properties of the devices would also have gustatory appeal.

We do not know whether the ability to analyse one's perception and to distinguish between different sensory modes is part of an elephant's cognitive abilities, since it implies an awareness of each sense as a distinct element. Humans tend to integrate all senses simultaneously; similarly, it is plausible that an elephant would gain experience and understanding in a synaesthetic and holistic way. At the same time, it is possible that changing a small part of one aspect of an interface element might have a significant effect on the overall experience, by targeting a particular sense.

Gustatory aesthetics

One of the things that engages all our senses simultaneously is food – unsurprisingly since it is vital for survival. In human food technology, quality criteria include mouthfeel, smell, taste, acoustics (e.g. crunch), colour and presentation.

It might be assumed that most non-human animals eat to live, with foragers spending such large portions of their time searching for and consuming food, and hunting occupying a significant part of predator time. However, non-human animals can also be selective and may make choices related to aesthetics as well as self-preservation (Shurkin, 2014). Our experience with Valli offers anecdotal evidence of food appreciation. One time, she was given a tiny piece of chocolate by her keeper as a treat; instead of chewing and swallowing it as she might have done with a cabbage leaf, she kept it in her mouth, swirling it around until it melted. One might suppose she was savouring the smell, the sweetness, the rich cocoa taste and the buttery mouthfeel, much as a chocolate-loving human would do.

For the reasons discussed earlier, it was important that during our research we tried to avoid food associations. On the other hand, we recognise that gustatory aesthetics would be an interesting topic for future exploration and most likely very popular with any non-human client.

Olfactory aesthetics

Strongly associated with the sense of taste is the sense of smell. Elephants initially use their trunks to smell the world around them. As we have previously discussed (*Chapter 4: Understanding elephants*), they have a large vomeronasal organ situated in the roof of their mouth. In order to perceive a scent in more detail, they may flehmen, which involves sniffing the scent sample with their trunk (akin to the nose in humans) then placing the trunk tip into the mouth to access this special organ. They can also detect chemical signals using taste.

Although chemical signals are synchronous, they may persist for hours or days or months once the object or event they signify is no longer present. Their range is both near and far, depending on the senses of the perceiver and external factors such as humidity and wind. They are therefore a 'material' that is hard to control. Furthermore, as we have indicated earlier, humans currently have a poor understanding of olfaction, epitomized by a lack of vocabulary to describe different aromas. This made it very challenging to use smell in our designs, as we were unable to discriminate between smells as well as an elephant, nor could we identify all the aromas contributing to the scent of any object.

We did consider some early enrichment concepts that used olfaction. These concepts included scent trails in the environment, stool samples from hitherto unknown conspecifics, and 'pungent boxes' to explore. However, none of these concepts gave the recipient much control over their experience because smells are pervasive (like sounds) yet have no reliable 'volume control' due to factors such as air temperature and substance volatility. Only the pungent boxes afforded a measure of choice if the olfactory stimulus was weak. Although every crafted object that we subsequently developed was permeated with scents that an elephant could discern, and which therefore contributed to the overall aesthetic experience of the device, as mentioned above, we were not in a position to appreciate the effect of and make decisions about this property of our designs. We therefore directed our attention to alternative sensory stimulation.

Visual aesthetics

Early on, we rejected the idea of developing visual interfaces such as giant touchscreens, partly due to the associated cost, and partly because elephants have limited visual acuity. As we have discussed (*Chapter 4: Understanding Elephants*) African elephants can discriminate a gap of 2.75cm about 2m from their eye – in other words, at the end of their trunk – while Asian elephants can discriminate at a much smaller distance (0.5cm) (Shyan-Norwalt et al., 2009). However, anecdotal evidence from the Elephant Voices site (ElephantVoices.org) suggests that elephants can recognise shapes very well, and that they can determine small changes in another elephant's demeanour from a significant distance – when a human might require binoculars.

When testing with elephants, we noted that if our devices were not visible to them, they were less willing to interact with them than when they were visible. Early prototypes were placed in areas of the elephant's environment that were trunk-accessible but hidden from view. Valli needed to be shown that a new device existed, which turned out to be a problem because one of her care givers used fruit as an olfactory lure. Having established that bananas might be a feature of the new experience, other pleasures became insignificant for her, so we were unable to gauge her interest in alternative sensory aspects of the design. Later, in the zoo environment, we installed a prototype radio that would allow the two resident African elephants to touch buttons in order to trigger different sounds. Our system was placed above eye-level, and initially ignored by the elephants. Only when they were far enough away to spot a new object mounted on the fence did they spontaneously return to engage with it – exploring and triggering the buttons.

Since it is known that elephants have dichromatic vision (they see yellow, blue, black, white), we used appropriate colours in one of our later prototype controls. This was a panel of touch-sensitive buttons, which were differentiated using a range of materials that offered contrasting colours, textures, positions on the controller and scents. This was the only device that used colour (yellow and blue) as well as visual contrast design features. Video footage analysis of Valli investigating the control showed that she was interested in exploring the surface with her trunk. Although we do not know whether vision played a role in her tactile exploration of the object, it is plausible that its striking visual appearance would have attracted her attention and enticed her to interact with it. Yet, this could not be true for Lakshmi, who is blind. Keepers reported that after *she* had located the device, Lakshmi visited it repeatedly until she had dismantled it.

When it comes to humans, past experience (memory and cognition) enables them to tell, for example, if the embers are hot when they look at a fire. Therefore, human awareness of colour has an obvious fitness benefit, although at close range temperature sensation would render vision redundant. It is plausible that colour perception could be similarly grounded in elephants' biology and that colour might have a useful place in the elephant-interaction-design palette. We established that other visible features (size, shape, pattern, location) could also be perceived using alternative modalities, such as smell and *touch*, if such features were presented in a suitable format.

We indicated that we were interested in exploring *acoustic enrichment* for elephants through our research and, as work progressed, elephant interactions highlighted to us that there was a strong connection between their *acoustic and tactile* perception – which may be the case for most animals. '*Hearing is the process by which the ear transforms sound vibrations in the external environment into nerve impulses that are conveyed to the brain, where they are interpreted as sounds. Sounds are produced when vibrating objects … produce pressure pulses of vibrating air molecules, better known as sound waves*.' (Britannica.com, 2020) We therefore took care to make well-reasoned design choices regarding the auditory and tangible properties of the different elephant-facing devices, presenting a range of interaction devices over time, starting with static controls and gradually introducing moving systems. Since auditory and tactile features became focal points of our work, we discuss them in detail in the next sub-section.

6.2.6 Auditory and Tactile Aesthetics

Auditory signals are synchronous with their production, and then they dissipate. The distance that the signal carries depends on how quickly the waveform attenuates, which in turn depends on environmental conditions such as weather and landscape. Low frequency infrasound (10-20 Hz) is outside normal human hearing range but persists over much longer distances than higher frequency sounds, which we know is used by whales and elephants to communicate with conspecifics. As well as seismic vocalisations, elephants can generate infrasound using their feet. An elephant stomp can travel up to 32km, depending on soil type for attenuation (O'Connell-Rodwell, 2007).

As discussed earlier, elephants can detect infrasound through both bone conduction and somato-sensory perception. Their inner ear has an enlarged malleus, which provides a bone-conducted pathway for seismic signal detection. Elephants can occlude the opening of their ear canal, potentially building pressure in the air canal to enhance bone conduction. In addition, they possess an aerated skull and sinuses, and fatty deposits which may act in a similar way to acoustic fat in dolphins and manatees – facilitating low frequency detection (O'Connell-Rodwell, 2007).

Rather than use samples of music, our initial intention was to synthesise some sounds with low frequencies (infrasound), so they had waveforms in common with elephant rumbles. The rationale for this was that while humans appreciate musical harmony, there is minimal evidence of other mammals finding it interesting. Uetake et al. (1997) report that 'classical music' influenced cows in a positive manner prior to milking, but Ritvo and Macdonald (2016) discovered no benefits for orang-utans subjected to 'music', while Wells et al. (2006) noted a tendency in zoo-housed gorillas to show less stressful behaviours when exposed to either 'classical music' or environmental sounds (such as rain forest). We then concluded that it would offer more control and choice if we were to develop digital instruments that could be operated by an elephant, allowing the animal to control the quality (volume, frequency, timbre) of the sounds being produced. We therefore spent a significant amount of time investigating how we might create acoustic experiences that would be interesting for them.

We identified the didgeridoo as an instrument capable of generating a potentially interesting acoustic waveform. This was because of the inherent similarity between the shape of the instrument and the shape of an elephant trunk; indeed, the kinds of sounds produced when air vibrates inside a didgeridoo have characteristics in common with some elephant calls. On analyzing African elephant calls that we downloaded from the open-source repository at ElephantVoices.org, we were able to see typical wave shapes and peaks. We therefore investigated this further by running an FFT (Fast Fourier Transform) analysis of (i) an African female elephant rumble and (ii) a didgeridoo sample, showing a strong similarity in shape (see figures in *Chapter 5: Design and Craft – Workbook: Output*). Unfortunately, there was less data available on Asian elephant vocalisations.

Initially, we played short low frequency audio samples (sine waves) to Valli, to determine whether she might have interest in low frequency audio. Keepers interpreted her posture and reaction, concluding that she appeared to show most interest in samples in the 60-70Hz range. Interestingly, Ayers and Horner (2007), identified the fundamental frequency of a didgeridoo as 62.5 Hz with small peaks at 174.5 Hz and 187 Hz.

Recording sound, which is essentially an ephemeral phenomenon, involves capturing and recreating sound waves. Analog recording can be achieved by using a microphone to sense changes in sound waves then transcribing these mechanically onto a (vinyl) record or magnetic tape. Sound reproduction reverses this process. Digital recording uses a sampling technique to capture audio data picked up by a microphone, storing the sound as a series of binary numbers. The different file formats used to store audio data vary in the quality of sound they can reproduce. To reduce the file size, algorithms (codecs) have been developed that remove audio data that is outside normal human perception – but probably not outside normal elephant perception. This may reduce the quality of acoustic experience for elephants being played pre-recorded music and other sound effects. The sound quality is reduced at different stages – not only by compressing the digital file, but also at the point of playback, when speaker size has an impact on the range of frequencies that can be recreated.

We hypothesised that using a physical resonator (which creates an uncompressed sound) might hold more promise for generating interesting acoustics than a digital file with amplifier and speakers, unless the quality of recording and playback were exceptionally high. Since low frequency vibrations are 'heard' via bone conduction, this suggests that resonating foot plates might be a more appropriate output device than a speaker. Moreover, research has shown (Honing, 2019) that bone strength is improved in a range of mammals (including humans) when they are treated with 20-50Hz low frequency vibration. Perhaps another good reason for elephants using low frequency rumbles (antiphonal calling) to communicate within herds is that they pick up the vibrations through their feet and transmit them via bone conduction to their skulls – thereby simultaneously strengthening their leg bones that have to support a huge body weight.

These reflections resulted in the investigation of alternative methods for the delivery *and control* of acoustic signals, which an elephant could potentially discern using *touch*, thereby directing our research towards haptics and kinaesthetics.

Rasmussen and Munger (1996) analysed the sensorimotor specialisations in the trunk tip of the Asian elephant and concluded that it was a very sensitive apparatus. They compared the sensory capacity of the trunk tip to the lip tissue of monkeys or to the mystacial skin surrounding a rat's whiskers, stating that this finding correlated with the tactile ability of the trunk, which can grasp small objects and place them into the vomeronasal organ for chemosensory processing. While elephants' trunks do not possess mechanisms that respond to dynamic changes or control motion and grip, they do possess mechanisms that respond over a larger area to vibrations and changes in pressure, hair-cells for the perception of form and texture, free nerve endings and other receptors (Hoffman et al., 2004).

During our investigations, we became increasingly aware of the elephants' interest in the tactile qualities of our devices. For example, when we presented a large push button made from an old sewing machine pedal, Valli never voluntarily pushed it, but she did spend several minutes exploring the ridged surface and running her trunk tip around the wooden frame. It was not clear if she was feeling or smelling the interface, or indeed perceiving it with both senses simultaneously. As a consequence, during our system's interface design process, we made various aesthetic design decisions in an attempt to enhance the tangible experience of the interaction. As a case in point, initially we offered rounded shapes, taking care to cut out circles instead of squares in an attempt to be less formal and more 'natural'. However, corners and edges seemed to generate as much interest from Valli as curves and, moreover, they were simpler to manufacture. We also observed that perfect circles are geometric, rather than organic, and therefore equally out of place in an environment that purports to be natural, or that aims to educate visitors about an elephant's natural habitat (see Figure 29: Shape and Form).

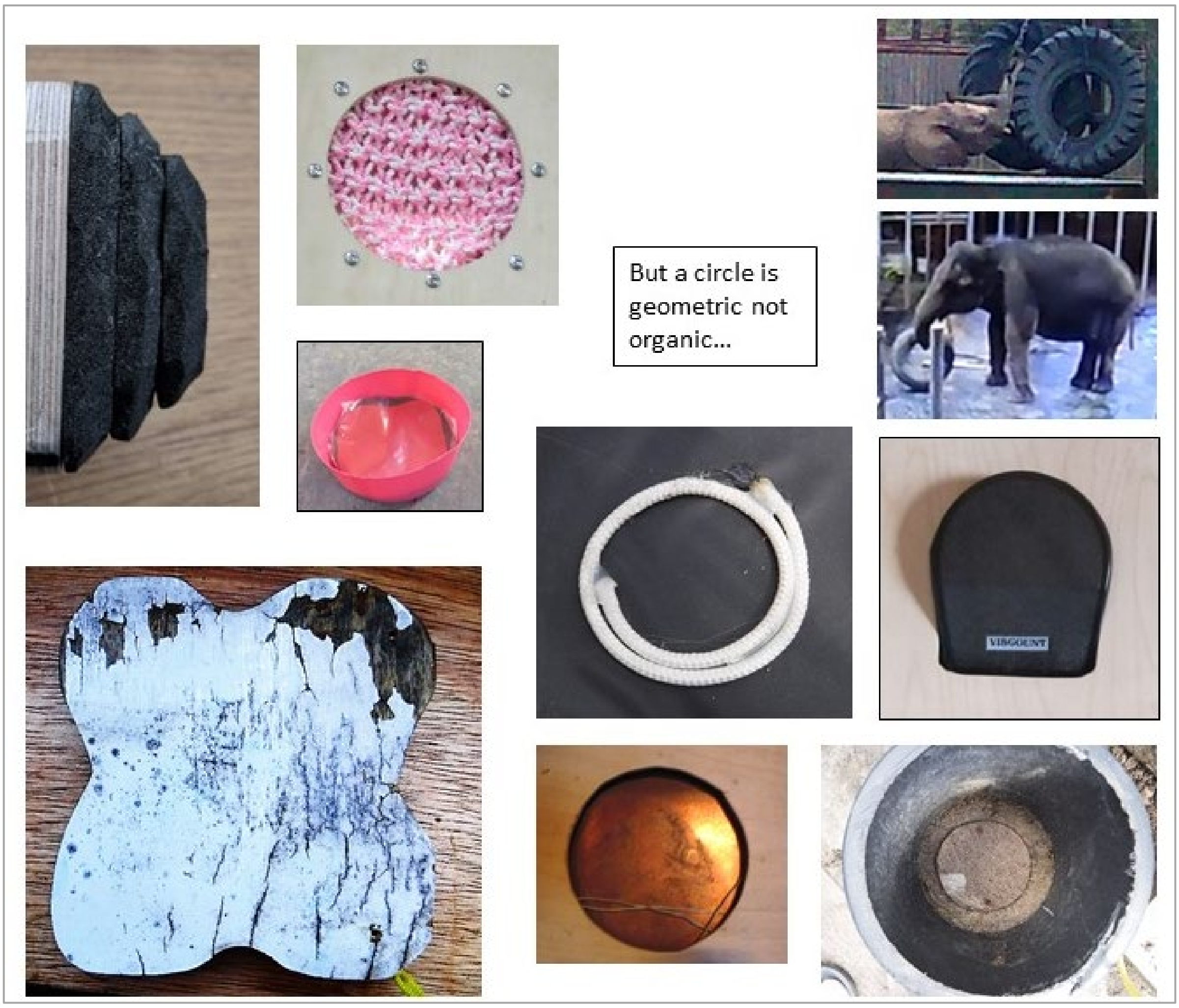


Figure 29: Shape and Form – range of rounded objects used by elephants

Over time, we experimented with a variety of surface details, repurposing existing items and crafting new textures from natural materials (see Figure 30: Materials). We discuss the potential of craft to unlock some of the subtleties of designing for non-humans in the subsequent section, *Craft as Mediation*. With regard to materials, we paid particular attention to certain qualities – temperature, weight, plasticity – that can only be perceived through touch. Variable temperature (for example, of a water supply) was beyond our scope due to cost implications. The weight of our installations was a compromise between making them sufficiently robust and making them portable and easy to mount and dismount. Objects with embedded technology were securely fastened with bolts and the base structures were constructed from 20mm sustainable wooden ply. This meant that the elephant would not gain any kinaesthetic feedback from weight.

Regarding plasticity, we found this to be awkward because we were unable to produce an electronic device that was both safe and flexible. Hanging ropes offered motion, but a digital signal was difficult to capture accurately in order to map movement to output. For this reason, controls were mostly rigid. On the other hand, we were able to embed tactile haptic feedback into devices in the form of tiny vibrating motors, which we believe would also provide low frequency audio that an elephant could perceive.

In relation to touch, it is evident that elephant *performance* is critical to enable certain sensations – for example, the trunk must be moved across the surface of an object to feel the texture and discern the shape, which is achieved by *haptic perception*. In our example interfaces, Valli's action was seemingly always a *kinaesthetic perception*, and presumably always offered some kind of *tactile* feedback because the interaction was with a physical object. There seems therefore to be a strong link between performative and sensory aesthetics – a symbiotic relationship whereby action enables sensory perception and sensory perception informs action.

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Materials

TEXTURE
Rope, canvas, hand-made knitted textile, aluminium wire, plastic contours, smooth copper sheet, sandpaper, felt, wood, leather, card, hessian knots…

MOVEMENT
Vibrations, swinging rope, sliding and rotating mechanisms, water features

COLOUR
Elephants can distinguish between black/ white / blue / yellow

SMELL AND TASTE
A mystery. Every material has its own scent + all the scents associated with handling and connected materials and previous sniffs in any case. Not something we can analyse or interpret yet.

WEIGHT
Most objects are securely fastened so weight should be minimised to facilitate human management – but free-standing objects (tyres, tree trunks) should be substantial so they can't be tossed around to damage things.

VARIETY
Testing with smooth and contoured/rough surfaces, edges and curves, hardness and softness

CONTRAST
Framing one material with wooden border provides fixings and security and identifies the location for touching.

HARDNESS
Can be hard, sharp, fuzzy, squelchy, soft, pliable, springy…

CONSTRUCTION
Some natural materials, some hand-crafted textile from natural, some machine-worked textile, some manufactured (copper sheet, plastics)

LINE
2D image – elephant can spot a new object from a distance but seem to be mostly interested in its form and feel.

HARMONY
Is this relevant? Can we imagine what it might be for an elephant?

PATTERN
There are patterns in nature, but mostly irregular repetition of shapes, not like wall-paper.

Figure 30: Materials – different properties explored in the context of elephant interactions

6.2.7 Performative Aesthetics

All the devices installed in the elephant enclosures required *interaction* on the part of an elephant, and so far, we have considered some pertinent sensory aesthetics, such as whether an object is interesting to touch, whether it smells or is clearly visible. These features are designed to attract the user to the device in the first place, while acoustic elements are part of a system design that aims to offer interesting feedback and make the device 'sticky' (enticing). We believe that it is important to make the interaction experience pleasurable and this is why we explored the design of analogue systems that allow greater control and discrimination regarding the nature of the system's output. We realised that for elephants, and arguably other animals, *performative aesthetics* is critical for both sense-making and engagement.

Our early designs focused on functionality with regard to mechanism of activation, and we found that tactile interfaces with hidden sensors worked better than switches that required active pressure (French et al., 2018). It is plausible that an elephant would quickly learn to touch or not in order to trigger a reaction and thereby have a choice but, initially at least, these designs force researchers to take a 'clandestine' approach because the elephant's actions are picked up by the sensors whether she intends it or not, which *subverts* the aim of providing control; the input data capture is *covert* and automatic.

One early prototype aimed to afford Valli control over her water supply, by offering a choice of two buttons – one triggered a jet of water, the other a fine spray. When these shower fittings were left in place overnight, Valli destroyed the control system by grasping wires attached to a microcontroller mounted *on the other side of the balcony fence*. She subsequently ripped the cables into bits, managed to reach the water pipes providing the shower and apparently '*had a lot of fun with it!!'* (quote from keeper). From the keepers' point of view, this activity had been enriching for Valli, exciting her curiosity, allowing her to express herself physically while engaging with a novel object in her enclosure, and testing both her dexterity and her strength. They believed that the experience would have given her cognitive, sensory and physical stimulation (although clearly not in a way we had planned or foreseen). Accordingly, we might need to rethink the kinds of system we offer an animal as large and strong as an elephant, if we want them to engage enthusiastically, using their full physical capacity without destroying the source of the fun.

We observed an example of a more substantial source of entertainment when watching night footage of Valli. We noticed that she spent a large portion of her waking time interacting with a tyre – a large, robust physical object, too heavy to throw but light enough to be manoeuvred. Firstly, she selected one tyre, then she rolled it close to her. She kept the tyre balanced under her body for over an hour, walking around while maintaining it in this position between her legs.

Figures 11 and 32: Valli plays with special tyre - video stills from https://vimeo.com/showcase/6353326

When we subsequently discussed this behaviour with a keeper, he explained that this tyre had a long history. When Valli arrived as a calf, over 30 years ago, that tyre was her first toy and accompanied her at night when she slept. Around 2010, a new elephant shed was built for her. In order to facilitate the transition from old draughty-but-familiar shed to new heated-accommodation-with-pool, her keeper asked her to pick up the tyre and carry it into the new building. Thus, her willing relocation of the tyre was the embodiment of her autonomous choice to move; the act of physically bringing it into a new environment gave Valli control over what was happening. Although there are now several tyres in the elephant compound, Valli seems attached to this one in particular. It could be argued that this shows how the tyre (manmade, unnatural shape and material) has come to represent a more general (or even universal) concept of home and security for her.

As a result of our findings regarding Valli's interest in objects which could be moved and which reacted in a way that offered kinaesthetic feedback, we tried hanging ropes, which proved popular with both elephants, but especially with Lakshmi.

More recently, we designed a large volume control slider made from repurposed drawer runners (shown in *Chapter 5: Design and Craft: Workbook – Input*). The slider thumb (old scrubbing brush) moved freely up and down the track, changing the acoustic output. When the device was installed, Valli and Lakshmi showed little interest, but the CCTV footage later revealed that they both touched the device several times during the first evening. The following day, Valli pulled off the thumb and 'groomed herself' with it, according to keepers. That brush had been selected by us for its texture and possible collection of enticing smells; it was sourced under a bench in a back garden in Battersea. However, to Valli, it was clearly an object she associated with bath-time and her usual grooming procedure – except that it was unaccountably stuck on a moving thing. (Of course, that was no problem for an enterprising pachyderm.) The brush was re-fixed more securely and subsequent footage shows Lakshmi sliding the thumb up and down the track during the night on several different dates.

This example illustrates how challenging it can be for human designers to appreciate a non-human animal's sense-making. For a start, we do not have access to their memories, so it is impossible to know what associations they make with different objects or scenarios. We cannot ask questions using language in the usual way, we can only observe what happens and make inferences based on *body-language and reaction*. Indeed, actions are easier to measure than emotional responses when we lack a shared interspecies language with which to explain subjective experience, as widely acknowledged by animal behaviour researchers (Dawkins, 2007).

With hindsight, and intimate knowledge of bathing protocols, we might have expected the brush to be recognized as a grooming tool, thereby transforming our carefully designed slider-controlled acoustic toy into a noisy scratch dispenser. In point of fact, researchers (and even keepers) found that the elephants often surprised us with their behaviour, which we found to be enlightening. Again, this highlights the importance of offering opportunities for animals to make *choices* if we want to understand their preferences and underlines the value of enabling *physical interactions*.

Object play in elephants occurs throughout their lives and is a pleasurable experience (ElephantVoices.org; Webber & Lee, 2020) which suggests that it could be a measure for performative aesthetics – for example, by capturing duration or consistency of object play. As McGonigal (in Walz & Deterding, 2015) has pointed out, play involves free improvisation: '… *we discover and reinvent purpose as we go along, constantly evolving our actions with great spontaneity*' (p.654). Play is grounded in the promise of a pleasurable experience (Flanagan in Walz & Deterding, 2015), an idea that fits very well with our emphasis on enhancing the aesthetics of our designed objects.

Objects designed for human play often have affordances that suggest how they might be used. Although these may be innate properties of the design, such as the smooth surface, spherical shape and bouncy material of a ball, their real-world applications still have to be initially learned through interaction. As mentioned above, an elephant that encounters an interactive device will also have to learn how the device works by exploring the interface, manipulating controls and paying attention to the feedback. Although animals can be trained to perform such tasks, one of our goals was to make our devices intrinsically appealing so that the elephant would take pleasure in playing with them.

Although all our interfaces had a performative aspect that required trunk movement to trigger an output, only some provided simultaneous haptic feedback that was directly mapped onto the action of the elephant, thus potentially offering a clear sense of control. A case in point is the slider example we discussed earlier in this section. Friedman (2017) suggests that a slider encourages '*exploration rather than precision*', which is exactly what we needed from an analogue control that could enable an elephant to modulate the pitch, intensity or tone of a digital signal. Our research with elephants showed that *exploration* of the environment was one of their key behaviours, likely associated with their foraging habits, but also part of their innate attentiveness (Seltman et al., 2018).

At first, we would not expect an animal to understand the mechanism of a slider. However, in designing the object we made important aesthetic decisions. The *thumb* was designed to be visually distinct and have tactile interest, thus inviting the elephant to touch it (in this is was successful). The smooth movement along the *track* required only a light touch; moreover, the boundaries of the object were obvious to see and also to feel when the thumb reached its limit. The slider solicited action and, in doing so, it facilitated the *learning* of it – its sensory and performative aesthetic dimensions facilitated the elephant's interactions and consequent understanding of the slider as a control mechanism (after the brush had been replaced securely).

We argue that interaction designers focusing on animals might design intrinsically better systems by considering the performative aesthetic dimensions of their products. Because humans make the decisions about purchasing animal-related equipment, designers may be tempted to appeal to the buyer's sense of aesthetic rather than to that of the non-human user. However, this could impair the user experience and therefore the very functionality of the product. For example, an animal user might choose not to play with a game that did not satisfy its sensory experience, which would defeat its original purpose. Moreover, von Gall and Gjerris suggest that there are positive welfare implications relating to aesthetics, in that they may increase an animal's pleasure (2017).

6.2.8 Wrapping up

This section has addressed our second research question: '**What playful technologies would elephants engage with, and how could these systems be designed to enable elephants to interact with them?'** We understand that the first part of this question has an infinite number of answers, but we have established that *moving control systems* have a strong potential to engage elephants.

With respect to the second part of the question, we have identified key design features required for an interactive device aimed at elephants – *differentiation, consistency, graduation, singularity, multiplicity and affordance* – and we have explored how these features can be realized through different aesthetic dimensions. Our work has focused on *acoustic, tactile* and crucially, *performative* *aesthetics*. In addition to this, we have described our initial design values and explained how these underpinned our work. We have also explored what it means to be an ACI designer, trying to imagine the experience of perceiving and engaging with technology as a non-human species.

The next section considers the physical aspects of our work in more detail by discussing the value of craft and thereby elaborating on our methodological approach.

6.3 Craft as Mediation

We have described some of the conceptual possibilities and challenges associated with designing for (distant) elephants. Additionally, there were practical opportunities and issues relating to the crafting of the devices we wanted to test. But what exactly is 'craft'? Goldsteijn et al. (2014) define craft as '*a careful form of making*'; Huotilainen et al. (2018) analyse craft as a form of *embodied cognition*; Nitsche and Weisling (2019) reposition craft as being *inclusive of computing*, in the context of tangible interaction design. Several researchers (Niedderer & Townsend, 2010; Hallander, 2011; Nimkulrat, 2012; Zheng & Nitsche, 2017) make a strong connection between *craft* and *design research*. Some of the thoughts of professional craftspeople are shown in **Table 6**.

Table 6: What is craft? quotes from craftspeople

https://www.craftscouncil.org.uk/stories/15-makers-artists-and-designers-on-what-craft-means-to-them

Craft, to me, is about having a dream and bringing that vision into existence. It is a form of meditation, ***exploration****, divination, and* ***communion with the materials*** *– Melissa Meier, artist*	*Craft is about* ***making with meaning*** *– Ekta Kaul, textile artist*	*Craft is about expressing an energy; the* ***energy in the fingers and body*** *and the* ***energies of the heart and mind*** *– Laura Ellen Bacon, sculptor*
Craft is the ***outputs from my brain through material practice by using my hands*** *– the opposite to inputs such as reading, watching, listening … When we output something physically, we learn so much through all our senses* *– Junko Mori, artist and metalworker*	*Craft is* ***synonymous with art,*** *opening the door to an identical territory limited only by human imagination and the physical limitations of materials* *– Julian Stocks, glass sculptor*	*I explore through experimenting and play, but to really* ***tease out a material quality or process*** *that I'm interested in, to understand it deeply, craftsmanship and skill are key* *– Edmond Byrne, glass artist*
Traditionally craft is seen as the activity of making using one's hands, yet we understand it more generally as way of describing a ***process of putting things together very carefully****. In this sense we describe the qualities of objects, elements and structures appearing like something crafted, which is about understanding the way something is assembled and the time involved in its production* *– Benni Allan, architect*	*To me craft requires skill, constant practice, dedication and focus… Using your hands and acquiring dexterity,* ***learning new skills, solving problems and making things*** *is good for everyone* *– Lisa Hammond, ceramicist*	*The essence of craft is about* ***making and really caring about the results****, where it is more than just getting from A to B but being really passionate about whether the outcome matches up to whatever standards you had invented for it … Making gives a tacit knowledge of the material world which I believe is* ***really important for understanding*** *the place we inhabit and for feeling a sense of connection, respect and agency within our environments* *– James Shaw, designer*
Craft is most meaningful to me as a ***verb rather than a noun****, as repeated, cumulative or reductive actions* *– Keith Harrison, artist*	*Craft means* ***handmade creation****… it's been created from nothing and by someone's hands, leaving a unique piece* *– Fred Rigby, interior designer*	*Making and craft will always remain meaningful, positive ways of* ***being connected to our senses*** *and dignifying the world around us* *– Mark Reddy, artist and maker*

In this section, we discuss craft: (i) as a method for mediating between humans and objects through sensory and intellectual practice; (ii) as a method for mediating between humans, by supporting people to develop ideas organically and collaboratively; and (iii) as a method for mediating between humans and other species, by mutual engagement with a carefully designed object.

6.3.1 Mediating between humans and objects

When we started to craft our designs into physical artifacts, our underlying design values served us well. We reduced costs by repurposing existing items and devices, finding that appraising ready-made objects in order to use them for our designs was a useful creative exercise. Natural building materials such as wood and rope were easy to source. Older, 'softer' craft skills, such as textile creation, proved to be useful, as they made us focus on aesthetic aspects of the design that we were able to control as designers and makers. *Touching* materials and *feeling the heft* of an object often gave rise to insights regarding its aesthetic dimensions. The tactile qualities of our devices turned out to be highly relevant and, as designers, we would have missed this aspect if the concept had just been handed over to someone else to manufacture.

Similarly, *tinkering* with electronics (which we include within our practice of craft) was more fruitful for developing an appreciation of sensors and actuators than if we had used off-the-shelf solutions. There is some debate as to whether digital making that involves using embedded technology constitutes craft in the 'traditional' sense. Nitsche and Weisling (2019) state that it does and claim that the computer is the *mediating tool* in this regard, rather than the action of making, but we argue that tinkering with the functionality and recombining the interactive components can be considered a form of crafting – using sensors and wires instead of needles and thread. Appreciating the sensitivity and potential of the electronic equipment over time and through experimentation was akin to our experience of working with wood and rope. We only used computers to write code that was uploaded to microcontroller chips. We note that the outputs generated through our use of embedded technology were not objects – they were concrete, perceivable experiences, such as sounds and vibrations. None-the-less, they had aesthetic dimensions that we were able to discern and control through our practice.

The value of craft as a method for understanding material quality and connecting our human senses to the physical world – was also relevant in our ZooJam workshops. A key aspect of the ZooJam was the opportunity for participants to be in the same physical space, interacting with physical tools to conceptualise and demonstrate physical objects. One of the most useful and productive activities was the crafting and construction session, when colleagues were tasked (in their teams) with building a model of the device they had imagined, using a variety of making materials - cardboard, popsicle sticks, glue, pipe-cleaners, balsa wood, felt, modelling clay etc.

Crafting was an excellent way to focus the participants on practical and structural aspects such as the dimensions, materials, location and feasibility of their designs - exploring engineering and manufacturing constraints. At the same time, technical details and electrical hazards such as exposed wiring could be considered in relation to the overall design; this was made easier because of the three-dimensionality of the prototype and the fact that it could be manipulated in space.

Our annotated workbooks provide meticulous documentation of the craftwork undertaken, taking into account the *interactive* aspects of the devices. Through teasing out the motivations for design choices, we were able to reveal insights into the design space. Moreover, we found that we learned a lot about *one* elephant's preferences by carefully documenting our design decisions, made in the workshop, and closely observing her actions, performed in the field. Playtesting with Valli was critical – there were many surprises, leading to many insights. For example, when assessing 'usability' of a particular button, keepers confirmed that she was definitely capable of triggering the device and could easily learn to do so; yet on multiple occasions, she chose not to interact. Clearly, the device did not have '*intrinsic appeal'*.

The *functionality* was therefore as important as the *form* – devices needed to perform properly in order to be tested. We found that functionality was an easier to measure criterion than form. We were able to identify small, practical goals – for example, when designing input features for a control device, we attempted to capture elephant interactions using hidden proximity sensors, which required *calibration*; testing output included finding ways to *synthesise* different acoustic experiences. Using embedded technology, we tested different kinds of sensors as input devices and various acoustic and haptic signals as outputs, mediated through a micro-controller. The technical aspect of the development was facilitated by being able to access resources (libraries, etc.) that were available online in open-source repositories, as well as using Arduinos for rapid prototyping. In this respect, we became *part of the making community* (Lowgren, 2016; Locoro et al., 2017). In the making community, there is a culture of sharing and helping others remotely. The community (sharing) aspect of this grassroots movement is critical to its growth and popularity, and indeed the community offered us support through the network of developers prepared to share their methods and problem-solving techniques online.

While objects that *moved* were the most interesting ones to design, they were also the most challenging to construct and make functional. As it soon became clear that they held a lot of interest for their target users, this meant we had to invent new ways to capture the elephants' inputs. We therefore used a range of simple sensors to detect trunk interactions with our devices, comparing different solutions for capturing input using the following criteria:

(i) Digital and/or analogue sensing – knowing this was important for capturing input on a graduating scale.

(ii) Cost and/or simple to make – in other words, would keepers be able to create their own versions from our designs, and would we be able to make them ourselves?

(iii) Covert or not – this relates to both the ethics of data capture without explicit permission from the user and, perhaps more significantly, to how much control is being offered.

(iv) Modality of feedback, if any – it seemed likely that interface feedback might be conflated with simultaneous output.

(v) Accuracy – this relates to reliability and learned affordance, which imply consistency.

(vi) Power consumption – this was a practical issue to do with maintenance and using batteries.

(vii) Ease of use – the elephant's experience might have a direct impact on the functionality of the device.

The limitations and potentials of our various sensing devices are presented in **Table 7**. These results are based both on our analyses of the functionality of the solutions in a workshop environment and our experiences in the field with elephants. We soon discovered that what works in a clean laboratory might not work out so well in an elephant shed. It can be very hard to anticipate all the variabilities in conditions, and the only way to resolve this issue is to test the prototype in the space for which it is designed, with the target users themselves. For example, our working prototype set of pipe-buttons started to misbehave in the elephant shed, possibly due to the quantity of stainless steel in the construction of the environment. There seemed to be some interference between the capacitance sensors, such that triggering one button might also trigger the other. This is an example of a well-known problem for UX designers (lab v. field) that becomes exaggerated in the context of working with animals.

Safety in the context of using electronics in animal enclosures was another critical issue. Using low voltage DC power sources meant that the risk was minimal; however, we needed to be careful not to expose wires which the elephants would have grasped and pulled. This also gave rise to the power consumption issue.

TABLE 7: Potential and limitations of using embedded sensors in the context of animal interface technology		
SENSOR	POTENTIAL	LIMITATIONS
Capacitance sensor	Can be used for digital and analogue sensing – threshold or proximity. Simple to craft a basic home-made version from everyday materials (tinfoil).	Interference between sensors on a larger scale project. Interference from large amounts of metal typically used in animal enclosures (bars etc.) Requires constant small power supply (battery issues). Home-made version requires constant recalibration.
Push-to-make button	Requires a deliberate movement from user (not covert capture of accidental interaction). Tangible feedback from device as pressure is applied. Could be ideal for species that naturally push objects (with noses or fingers). Simple to craft from everyday materials. Suitable for digital control.	Might be an unnatural movement to expect the animal to perform. No indication whether it is in ON or OFF position.
Switch	Requires deliberate movement from user. Tangible and visual feedback from device, which remains in triggered position until switched back. Suitable for digital control.	Might be an unnatural movement to perform. Difficult to gauge the correct amount of pressure that should be applied. More difficult to construct at larger scale.
PIR (passive infra-red) sensor	Cheap and widely available, detects heat (proximity of animal). Suitable for digital control.	Wide angle sensing range, which needs to be focused/restricted to capture small interactions. Constant small power consumption (giving rise to battery issues). Covert data collection.
Ultra-sonic range finder	Cheap and widely available. Suitable for digital and analogue sensing. Accurate readings (to 3mm) within large range (e.g. 2 - 400 cm). Can be used covertly or in conjunction with moveable object that gives animal control.	Constant power consumption. Fixing must be accurate so that transmitter and receiver target exact position of object (beam can deflect).
IR beam-break	Tried and tested solution for many animals already. Simple and accurate – no moving parts. Suitable for digital control.	Could be triggered by insect or accidentally. Constant small power consumption. Covert data collection.
Variable resistor	Requires deliberate movement from user. In principle very accurate and offering good degree of control for analogue or digital input.	Existing versions are small - difficult to construct at larger scale. Turning and/or sliding might not be a natural behaviour to perform.

6.3.2 Human to Human Mediation: Co-crafting

Crafting models is an activity we have often experienced during our youth, but this mode of expression is often ignored in favour of sketches, which require fewer resources. However, not only does 2D visual representation put the final design in the hands of those who are confident artists, but a mark on paper becomes a kind of signature for its author – it can be erased or written over, but that is a deliberate and destructive act. Collaborative drawing can be fun and productive, as long as participants remain respectful of each other's contributions. We argue that co-crafting is more inclusive and offers a more flexible, unassuming editing process, comparable with co-writing documents or code on a shared platform such as Google Docs or GitHub (but without the version control). Physical pieces can be placed here or there until a decision is reached; paper and card can be lengthened or shortened easily; co-creation is such a *fluid* process that it is easy for everyone to become involved (Luck, 2018; French et al., 2019). To emphasise this point, we demonstrated that besides generating a range of exciting technology-enhanced enrichment concepts, the ZooJams enabled *collaborative multi-disciplinary practice* to happen while the workshops were taking place and offered potential for future projects. Moreover, a physical prototype was ideal for demonstrating functionality to others - it was easier for an audience to comprehend, acted as a showcase piece and facilitated the design team to appreciate the device from the animals' perspective. In a RtD approach to finding a solution to a brief, the iterative *making* of designed objects is emphasized in order to fully appreciate their qualities and to enable sharing and testing with users (Gaver, 2012). In this respect, a ZooJam, and specifically the crafting session, can be an early stage in a RtD process, stimulating fresh perspectives by facilitating new ways of framing old challenges (French et al., 2017).

By helping to build trust and respect between the technologists and the species specialists, networks were established, and colleagues were able to learn from each other through skills and knowledge sharing during the event. Thus, the experience was educational and transformative for participants as well as the wider academic community.

Back in the world of elephants, when negotiating with keepers, we realized that having physical products was also extremely helpful for the other (non-ACI) human participants in the design process, who could thus relate to the underlying concepts more easily. Human participants were also able to visualize systems in place when they were presented with objects they could touch and reconfigure themselves. Involving the keepers in the production phase of the prototyping was motivating for them, as they were able to invest their own creativity into the product. In this respect, creating rough prototypes was useful for forging collaborative practice with keepers, which in turn supported our attempts to enable participatory design with their elephants.

6.3.3 Mediating between species

It seems probable that devices for animals are more likely to be successful as tangible objects than as graphical interfaces, if only because animals might be expected to learn the relevance and purpose of a physical object faster than an abstract representation, since they use this skill as part of their normal behaviour (Wirman, 2014). Therefore, crafting physical objects became one of our priorities during our research – because we are designers trying to understand our users.

We have already suggested (and there seems to be agreement (Lim et al., 2008)) that a series of rough physical 'sketches', evolving over time, has more potential for engaging stake-holder collaboration than a high-fidelity version of a solution, ready to be tested. The less finished the piece of work, the more opportunities there are for others to participate in the design by contributing their own ideas. This flexibility can also be extended to the *animal users*, so that they also have the opportunity to make choices regarding the characteristics of the systems we design for them. It could be argued that this constitutes a kind of Participatory Design with the animal. However, since we lack the ability to explain to the target user what we have in mind as a final product, this means that the animal is necessarily missing some context and has to react 'on the fly' to whatever novelty is introduced. Yet perhaps this results in more honest feedback than if we had been able to say (for example): '*Look, it's going to be an exciting musical toy, but what do you think of this button so far?*'

We would like to draw attention to two parallel events – the choices made by designers that influence the final experience offered to the animals, and the choices made by animals if they are offered a way to express their preferences during the process of development. Designers' decisions will be heavily influenced by the choices made by their animal users, suggesting a mode of development that values incomplete solutions as sources of inspiration and knowledge. Moreover, in order to engage the animal participants, it is fundamental to create *physical interactive objects* that will ultimately be deployed by the stakeholders (designers, animal users, carers) as cognitive tools. A physical object was the only possible way we could express our abstract ideas so that elephants might be able to make sense of the devices we designed. As we indicated in the previous section, artifacts needed not only to be constructed but to be *crafted* (made by hand, with care and aesthetic consideration) in order to be reliably *shared*.

The value of craft to enhance the designer's sensory and intellectual appreciation of form and substance has been discussed in *Material Dimensions*. If we position this awareness within an ACI context, we see that craft may bring to the ACI designer a *heightened sensibility* of their animal user's potential experience. The profound experiential knowledge gained from physical interaction with an object is something *shared* between designer and user, despite their reliance on different modes of perception. As the design becomes more refined over time and craft skills mature, we argue that concurrently, there is an intensification of the insight of the designer into the perspective of the user.

For our research with elephants, personalization was a key factor. Elephants have individual preferences, as we have discovered, and captive environments are also unique, which meant that designing bespoke solutions was a requirement of the project. We were trying to develop something novel and tangible for a mysterious user – one whose physical and cognitive abilities with regard to manufactured interactive interfaces had not yet been mapped, and in consequence, there existed no interaction idioms on which to base our work. Although we undertook an ethnographic study in order to understand the lives of captive elephants and their keepers (*Chapter 4: Understanding elephants*; also French et al., 2014), this was specific to the elephant population we visited and therefore could not give rise to generalisations regarding captive elephants in the UK. For ACI designers, it is often the case that early prototypes are developed for a small cohort of users – individual case studies are common before large scale deployment of solutions. However, this means that quantitative feedback may be difficult to obtain. While it is therefore difficult to offer designs that will apply to all members of a species, RtD proposes that *particularity* can be an advantage. The design of a single, bespoke solution can offer valuable outputs by generating unexpected knowledge and by inspiring future directions for research. Keeping the *scope small* like this enabled us to spend time crafting different versions of our designs, thereby simultaneously learning more about our user.

While a data-driven scientific approach would require a statistically viable number of captive elephants to test a novel device under same conditions so as to authenticate results, we were able to justify the exploration of one elephant's preferences. We showed how knowledge obtained in a single case study could inspire and inform subsequent projects, as well as the work being an exemplar of the sustainability "3 Rs" approach mentioned in *Chapter 2: Background Research* (Replace, Refine, Reduce) to conducting experiments with animals. We found that focusing on the development of an interactive object for a specific and unique context garnered rich qualitative data that related to the behavioral responses of the animals to the artifacts. We started by expecting Valli to perform specific actions but we encountered unexpected behaviour; we ended up trying to provide engaging experiences and capturing what the elephant did, because it was impossible to know in advance which aspects would be interesting for her, or indeed for us as designers. In fact, this more fluid approach led us towards haptics and tactile stimulation, and from there to performative aesthetics. The insights we gleaned from the iteration of designs aimed at offering enrichment to one elephant (Valli) thus informed the direction of our research and enabled us to offer similar solutions to other captive elephants. This emphasis on particular, context-specific solutions therefore allows researchers to investigate individual problems in depth.

6.3.4 Wrapping up

The process of *making* a sequence of physical objects is a fundamental aspect of RtD, underpinning its philosophy of design. Redstrom (2017) describes the '*making through design*' process as '*building a conceptual place to work*', where the direction of the design expresses the worldview of the designers. In our project, the transition from concept to physical product (prototype) was challenging, but ultimately rewarding on several levels. **Crafting** - the process of working with physical objects – provoked a deeper reflection on the nature of the designed artifact and the nuances of design choices; for example, handling wood while considering how an elephant might approach the same task inspired new insights on the shape, texture and size of the design. As we have noted, this was also an important characteristic of ZooJams, where we encouraged participants to craft models of their ideas; moreover, to **co-craft** in order to facilitate collaboration.

Crafting and tinkering also contributed to '*understanding other*' because we became more aware of the sensorial aspects of the designed objects, and this brought into focus the aesthetic dimensions from an elephant's perspective. The objects were also regularly shared with elephants, whose reactions were absorbed into our motivations for design choices and subsequent iterations of prototypes. Craft was therefore instrumental in **mediating** between designer and elephant. This enabled us to analyse our concepts with more confidence and we therefore recommend ACI designers to adopt a similar approach to a new design problem, whatever the species. Our interpretation of RtD became Research through Design *and Craft*.

6.4 Ethical Reflections

In sharing our ideas with the wider community, some of the philosophy underlying the research is inevitably communicated. Therefore, it is important that the work is grounded in strong ethical principles that can be explained and justified to a broad range of people.

As the early part of the work involved research into elephant behaviour and conducting ethnographic studies, this involved gaining access to facilities that kept elephants. On a formal level, gaining access to elephants requires agreement from keepers and their institutions; all other associated stakeholders (such as The Open University) typically also require ethics agreements in place. Informally, the issue of ethics can be contentious within ACI communities - ACI practitioners are always raising questions about what actions or interventions on the part of humans can be considered ethical - and there is no general agreement, since the ACI community includes people from various disciplines with a range of views on appropriate relationships with animals. It is therefore critical to identify one's own stance and to be able to justify it with considered arguments, even if it is impossible to keep everyone happy.

Researchers who are part of the ACI community will undoubtedly have differing perspectives on the ethics of designing technologies for animals. As a case in point, North (in Zamansky et al., 2017) has stated: '*Build only what they want and need*.' We know that millions of animals are kept in conditions they neither want nor need, for example at the service of socio-economic systems such as the farming industry. Yet we could strive to improve their existence. As Mancini (2017) points out, some ACI researchers might be willing to engage with those systems in order to improve animal welfare and ultimately the status of animals in human society, suggesting that a shared ethical framework would need to be broad enough to encompass a range of values.

Additionally, we should be sensitive to the fact that devices for humans do not always meet the criteria of being both wanted or needed. Designers for humans are allowed the freedom to propose novel concepts that no-one knew they wanted (because they did not think of them and the artifacts did not already exist) and which clearly were unnecessary for survival or indeed welfare. Some might argue that computer games are a modern case in point.

We have already discussed how play seems to be beneficial for all species, and how it may enhance the experience of captive animals by providing cognitive, social and sensory stimulation, as well as exercise. As we explained when discussing the concept of environmental enrichment, opportunities for captive animal play can be devised that mimic survival strategies required in the wild. Markowitz

(1982) described this as *behavioural engineering* and countered criticism that his enrichment games were 'unnatural' by pointing out that the captive environment is contrived by definition. Since there is increasing recognition that games and interactive devices can play an essential role in stimulating species-specific behaviours (Quick, 1984; Young, 2003), our ethical position is that trying to develop these kinds of systems is always acceptable, if it is done with the aim of increasing the animal's welfare, whatever their circumstances.

However, we also need to be mindful of the potential long-term effect of our interventions. The focus for enrichment design tends towards finding immediate practical solutions that enable species-specific behaviours within captive environments, but there is also a potential for longitudinal studies that investigate how the introduction of novel devices impacts on a community of animals over time. Riede (2019) suggests that *niche construction theory* (how a species modifies its environment and thereby shapes its own and others' evolution) can explain human culture – that children's toys (object play) may lead to adults' materialistic behaviour and aptitude for innovation. What might happen to a group of primates, for example, who were continuously offered cognitive enrichment via playful objects in a restricted environment where overtly aggressive behaviour was curtailed? If choice was permitted in the selection of mates, would the animals with better problem-solving skills be more successful? Would reproduction favour brain over brawn? Would the animals begin to invest their creative energy into the development of other artifacts, following the example of chimpanzees at Belfast Zoo, who improvised a ladder from tree trunks so they could escape their enclosure (https://www.bbc.co.uk/news/uk-northern-ireland-47186124)? In the same way that humans have shaped the evolution of domesticated species, might our well-intentioned interventions have unexpected consequences for captive 'wild' animals? What, indeed, are the ethical considerations?

ACI researchers work in a field that is largely uncharted. Although connections between animals and technology have been made for many years, the careful design of novel *interactive* artifacts that support animals' behaviour, whether trained (e.g. tools for working animals) or natural (e.g. enrichment for captive animals), is a relatively recent topic for investigation. As a consequence, at some stage, much of the research involves *speculative designs* for future (non-existent) objects. Our ZooJam workshops attempted to address the need to design future enrichment solutions – experiences that did not yet exist. ZooJams invited people to be creative with concept development and subsequently critique their ideas through co-crafting (miniature) versions and obtaining feedback from experts who could offer opinions about how the devices might work in the field. As explained earlier, the ZooJam was a concept that evolved over three years as an offshoot of our main research. We were trying to imagine what kinds of technology-enhanced enrichment elephants might enjoy and began exploring different possibilities for generating ideas.

Design fiction also offers researchers a creative method for exploring the future with some rigour, while also being an egalitarian way of sharing ideas with the wider community, beyond academia. Of course, this is a uniquely human response to the challenge of assessing the impact of human interactions on non-human animals. To widely share the perspective of an animal, we could, for example, capture an animal's interactions with a system and post this information online, in the manner of streaming webcams (for example - https://hml.londonmet.ac.uk/Live/34). Yet this is not a choice made by the animal, and some people have claimed it is an invasion of privacy (Mills, 2010). Probably some domesticated animals would choose to share information with us, if it were possible (Lawson et al., 2016) but what reasons would they have to do this?

One ethical position is that such an arrangement should be *reciprocal*. This has been proposed in the context of dogs, suggesting for example, that a system providing information about a carer's imminent arrival might help alleviate stress (Hirskyj-Douglas & Lucero, 2019). Perhaps, using technology, we could allow elephants to shape OUR behaviour (as dogs do) in parallel to humans designing systems that an elephant is expected to learn how to use (thereby incrementally changing their behaviour, albeit in a positive way). In other words, technology might help us find new ways to capture an elephant's, or another animal's, *intention* in order to better serve her purpose.

We suggest that one way to achieve this outside laboratory conditions is to provide a moving interface element that requires the animal to act upon it, thereby deliberately adjusting the associated output. Such a control feature might reduce motivational ambiguity if the movement was precisely mapped to one specific changeable quality. In our research, we plan to take this concept further by crafting a range of moving controls for elephants and assessing them in terms of their aesthetic appeal, their robust functionality and their usability in regard to adjusting different features of the elephants' environment.

6.5 Looking forward

We have described and critiqued the different methods we used to tackle the challenge of researching, designing and developing interactive technology for elephants; we have discussed our design principles in depth; we have explored ways in which craft has underpinned much of our work.

In the next chapter, we summarise our contributions to the field and present them succinctly in a craft-friendly format, as a deck of cards that can be manipulated, shared, discussed and rearranged by a team of designers.

Contributions

Our research with elephants has generated the following contributions which advance the field of Animal Computer Interaction for any non-human species:

1. We have developed a useful methodology to support developers working on ACI projects – ***Research through Design and Craft***, adapted from RtD. Our exploration of *craft as a mediator* has revealed its value:
    a. for connecting the designer with materials through sensory and intellectual practice;
    b. as a communal activity that enables designers to work collaboratively;
    c. as a mediator between designer and user, through mutual interactions with the designed artifact.
2. We also developed a kind of workshop specifically aimed at bringing together experts from different fields to ideate on ACI design – the ***ZooJam***. Three such workshops have taken place so far, generating a range of goal-oriented concepts. A ZooJam fits well as part of our RtD&C methodology, particularly at the start of a new project. The jams have been shared with the community here: http://www.zoojam.org.
3. Building on previous work, we have identified six principles of interaction design as being critical for ACI interface development – confirming the importance of ***consistency and affordance***, and highlighting ***differentiation, graduation, specificity and multiplicity***. Graduation in particular allows the user to express detailed preferences regarding the *quality of the output* that is controlled by a system, thereby potentially enabling the user to make a contribution to the overall design.
4. We have explored the topic of ***More than Human Aesthetics*** in relation to ACI design, highlighting the need for designers to incorporate aesthetic dimensions into their designs. We have drawn particular attention to the need for *Performative Aesthetics,* both for engaging users and for enabling many other aesthetic dimensions.
5. Finally, in this chapter we propose a deck of ***Concept Craft Cards*** that we have designed to incorporate key insights gained during the development work for elephants, expressed as general topics for other ACI designers to consider. This is a work-in-progress, needing to be tested extensively within the ACI community and it will form part of our future development.

> The deck has been evolving since its inception, and we anticipate that it will continue to do so.

The rest of this chapter comprises the following sections: (i) Response to Research Questions; (ii) Concept Craft Cards; (iii) Scenarios Using Concept Craft Cards; (iv) Evaluation of Concept Craft Cards; (v) Summary.

7.1 Response to Research Questions

With this project, we have addressed three research questions:

1. Will captive elephants engage with playful technologies designed to enrich their daily experience?

We established that the answer is yes, but that it all depends on the nature of the playful technology.

2. If so, what playful technologies would they engage with, and how could these systems be designed to enable elephants to interact with them?

We acknowledge that in the realm of playful technologies, there are infinite possibilities. We were able to create some systems that engaged elephants and, in developing our designs, we began to appreciate some of the aesthetic sensibilities of particular animals. We investigated acoustic outputs, but much of our work was in the area of control system interface design, focusing on techniques for enabling and motivating elephants to interact with different devices.

We came to understand that moving objects hold considerable appeal for an elephant, as well as offering designers a valuable opportunity to assess user reactions – there was no shared language for asking relevant questions, but we were nevertheless able to capture actions and interpret them with keeper support. We became aware that performance was a facet of other modes of perception for an elephant, supporting touch, sight, hearing, taste and even olfaction. Moreover, we surmised that hearing and touch are so closely related in an elephant that it might be hard to disentangle acoustic and tactile signals into their specific modalities. As a result of our exploration of elephant aesthetics, we advocate the inclusion of 'performance' as another dimension of experience to add to the traditional five senses.

Our work involved research, ideation (developing concepts), and production and analysis (iteratively designing, crafting and testing prototypes). We took inspiration from the methodologies used by other ACI researchers, and also from the game design and design research communities. We adapted these to fit our work with elephants and thereby addressed the third research question:

3. What design methodologies would best enable designers to identify and develop the most appropriate designs for such technologies?

For our early research, we undertook an extensive *literature review* in order to understand more about the behavioural characteristics of elephants, followed by an *ethnographic study* of captive elephants at Colchester Zoo. We found that sketching from close observations supported our understanding of how a trunk is used by an elephant in a captive environment; creative writing was a useful method for trying to see the world from an elephant's perspective. Further insights were gained during our ideation and production phases.

As a catalyst for ideation, we adapted the concept of game jams to devise the *ZooJam* workshops, held on three consecutive years at the annual ACI Conference. The aims of the ZooJams were to provide opportunities for successful *multi-disciplinary collaboration* and to produce *conceptual and hand-crafted outputs* that met specific design briefs relating to animal welfare.

Ideation was also an important part of our *Research through Design and Craft* (RtD&C) methodology. The process focused on production and analysis, which consistently gave rise to new insights and new ideas.

As we have shown in our annotated design workbooks, prototype development and deployment took place over several years, from 2015-2020. An advantage of this gradual, intermittent negotiation was that it gave us plenty of time to reflect on each intervention, as well as time to develop suitable technical and crafting skills, and then integrate these reflections and competencies into the designs. Moreover, our impact on keeper time was restricted to a couple of days every four to five months, which meant that everyone involved had positive anticipation of the next period of testing – keepers were ready and willing to try new devices; designers were keen to make travel arrangements. On the other hand, the longitudinal nature of the study was imposed by the requirements of full-time employment and the remoteness of the elephant enclosures, rather than deliberately chosen. In practice, we would suggest reducing the time between interventions, if possible, so as to maintain project momentum. Regarding the procedure for evaluating prototypes, we would recommend a similar procedure to the one adopted by Noah's Ark Zoo, whereby a novel enrichment device is introduced to the enclosure while the animals are elsewhere, and left for them to discover independently, on the understanding that it is standard practice in most scientific investigations of enrichment.

Our RtD&C methodology was adapted from RtD and shares many of the salient features of RtD, such as keeping annotated workbooks, making a series of designed objects, designing for the future and focusing on particular rather than general solutions. For our project, the focus on a small number of elephant users, and on one elephant in particular (Valli), meant that we were able to explore bespoke design solutions and personal preferences in detail. If we had tried initially to create a device that could be used by any captive elephant in the UK, we would have run into insurmountable challenges relating to the context. For example, would the user be young or old, male or female, African or Asian, part of a herd or solitary, protected / free / no contact? What would the enclosure be like? What routines and existing enrichment opportunities would be in place? Therefore, the *specificity* of the design brief and the personal engagement of designer and elephant with the *same* crafted object was a positive feature of our work. In this regard, our approach fits well within a RtD tradition, where *particularity* is a highly regarded attribute of design.

Perhaps the main weakness of RtD for our purposes was its strong emphasis on the designed object rather than the user's interactions, whereas in the ACI community, practitioners emphasise the critical importance of *interaction design aimed at a different species*, and the *user behaviour associated with a device* that gives the designer insights into the animal's perspective. Our *deep exploration of craft and aesthetics* that was part of our RtD&C approach optimized both the *empathy* of the designer and the *engagement* of the animal user. Through a process of trial and error, we gained valuable insights into a previously unknown problem space. Although these insights referred to specific incidents, many of them point to a bigger issue that has relevance beyond any particular incidents that occurred while working with elephants. Furthermore, we suggest that each understanding of a situation can be expressed in more general terms as a guideline for future developers of technologies for different species and may also have resonance in the sphere of human-computer interaction and user experience design. This collection of insights constitutes one of our key contributions to the ACI community.

We have collected our insights as a deck of cards, representing the first iteration of a toolkit for ACI developers. At the top conceptual level, we offer suggestions for ACI developers embarking on a new design journey; the next conceptual level considers user experience and offers our recommendations for interaction design that values cognitive and sensory enrichment; at a practical level, we provide a set of topic cards, to be used during development to support the realization of concepts.

The reasons for presenting our contribution in this format are twofold. Firstly, the deck becomes a scalable, shareable output to which other researchers can contribute. We include blank cards for others to write, based on their own investigations, to create expansion packs. Secondly, the format allows developers to freely associate ideas and suggestions, which is helpful because there are many links between the individual cards. A novel system designed for a non-human animal typically follows a cyclical development process rather than a linear one; it is always exploratory and often speculative. The cards are not intended as an ideation deck, to be shuffled and shared randomly; rather they represent a collection of our findings as designers, inspired by and specifically related to our work with elephants. However, we propose that the insights gained from this approach have relevance beyond working with elephants and that therefore the Concept Craft Cards could be used as part of a toolkit in other ACI design contexts.

7.2 Concept Craft Cards

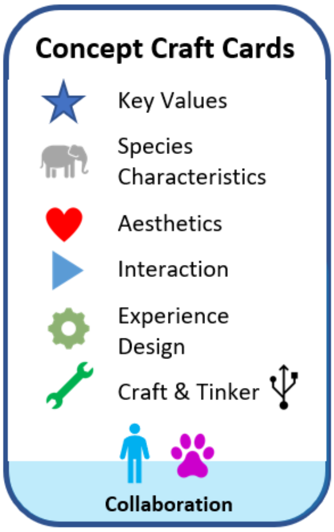
A deck of theoretical and practical topics for ACI developers to consider.

The 55 card deck comprises the following sets of cards:

(i)	Key Values	(3 cards)
(ii)	Species Characteristics	(7 cards)
(iii)	Aesthetics	(11 cards)
(iv)	Interaction	(6 cards)
(v)	Experience Design	(15 cards)
(vi)	Craft and Tinker	(13 cards)

We envisage an individual or team of designers finding these cards useful at different stages during a project. One of the points we have emphasized during the description of our work is the value of collaboration – as part of teamwork and for sharing knowledge and expertise. We believe that using a deck of cards facilitates a collaborative environment, where discussion points (physical cards) can be linked together and moved freely around a table, apportioned to different people or juxtaposed in relevant and thought-provoking ways. Just as co-crafting can focus participants on the finer aspects of a design and enable fluid creative expression amongst a group of designers, so can a set of cards inspire members of a design team. Additionally, since one person isn't in charge of a list, or taking minutes, or indeed holding the whole deck, using cards can empower participants. There are blank cards available for people to add their own ideas, and a snapshot of the tabletop can provide an instantly shareable, visual reminder of the discussion at a moment in time.

Moreover, cards are associated with creativity and spontaneity – a playful approach that values a surprise element, action and reaction within a clear framework. We hope that everyone will find something they appreciate and that gives them inspiration within the deck. In this section, the cards are described and then two scenarios of use are presented to illustrate how the deck may be used by others in practice.



Key card

This card is the **key** to the deck, showing the icons associated with different sets.

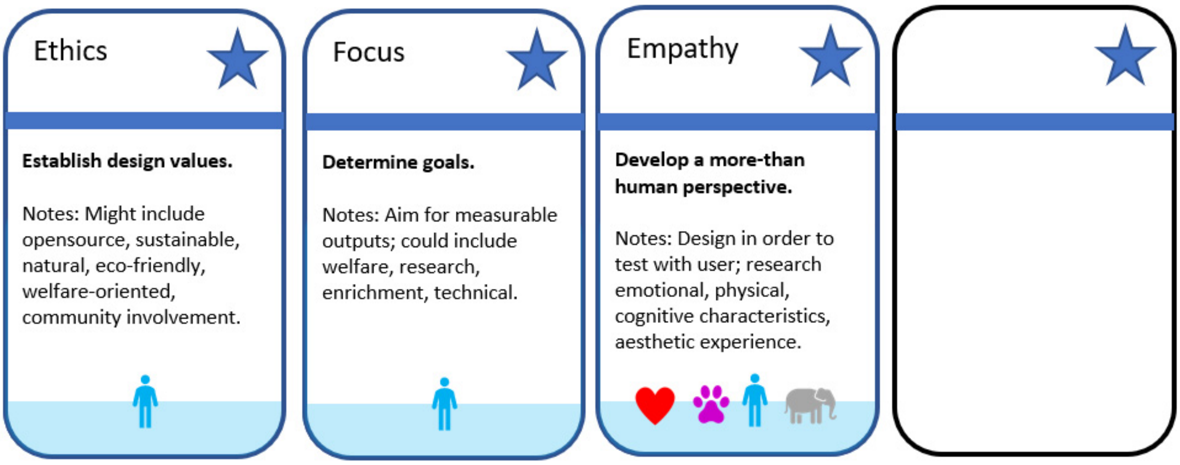
The two icons at the base represent human and non-human collaboration, indicating whether either or both are required in order for the practical part of the card topic to be achieved.

Each card may be linked to other sets, and this is indicated using icons at the base.

Figure 33: Full deck of Concept Craft Cards

(i) Key Values

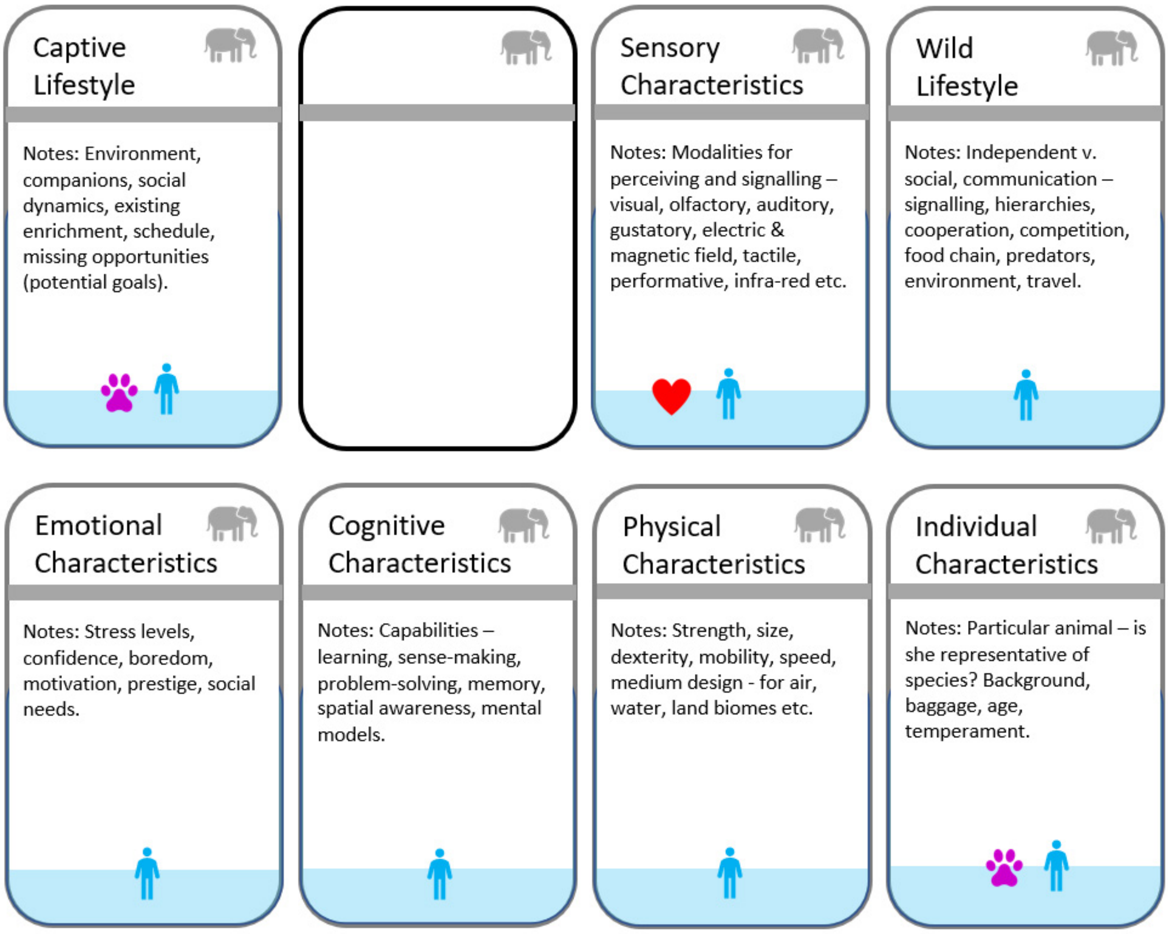
Initially, we might expect people to consider the three *Key Values.* We derived these values during our project with elephants, finding that our early design values provided an **ethical** foundation for subsequent prototyping. Our **focus** was clear, as the work was grounded in meeting enrichment goals, but we were also aiming for research outputs and had many technical challenges along the way. For us, the ethnographic study paved the way for gaining **empathy**; we found that all encounters with elephants enriched that capacity within the designers.



We have included a blank card in each set (see Figure 33), to indicate to users that this pack of cards is an evolving piece of work and that we welcome contributions from other designers. Different projects will undoubtedly give rise to different insights that can enrich this collection.

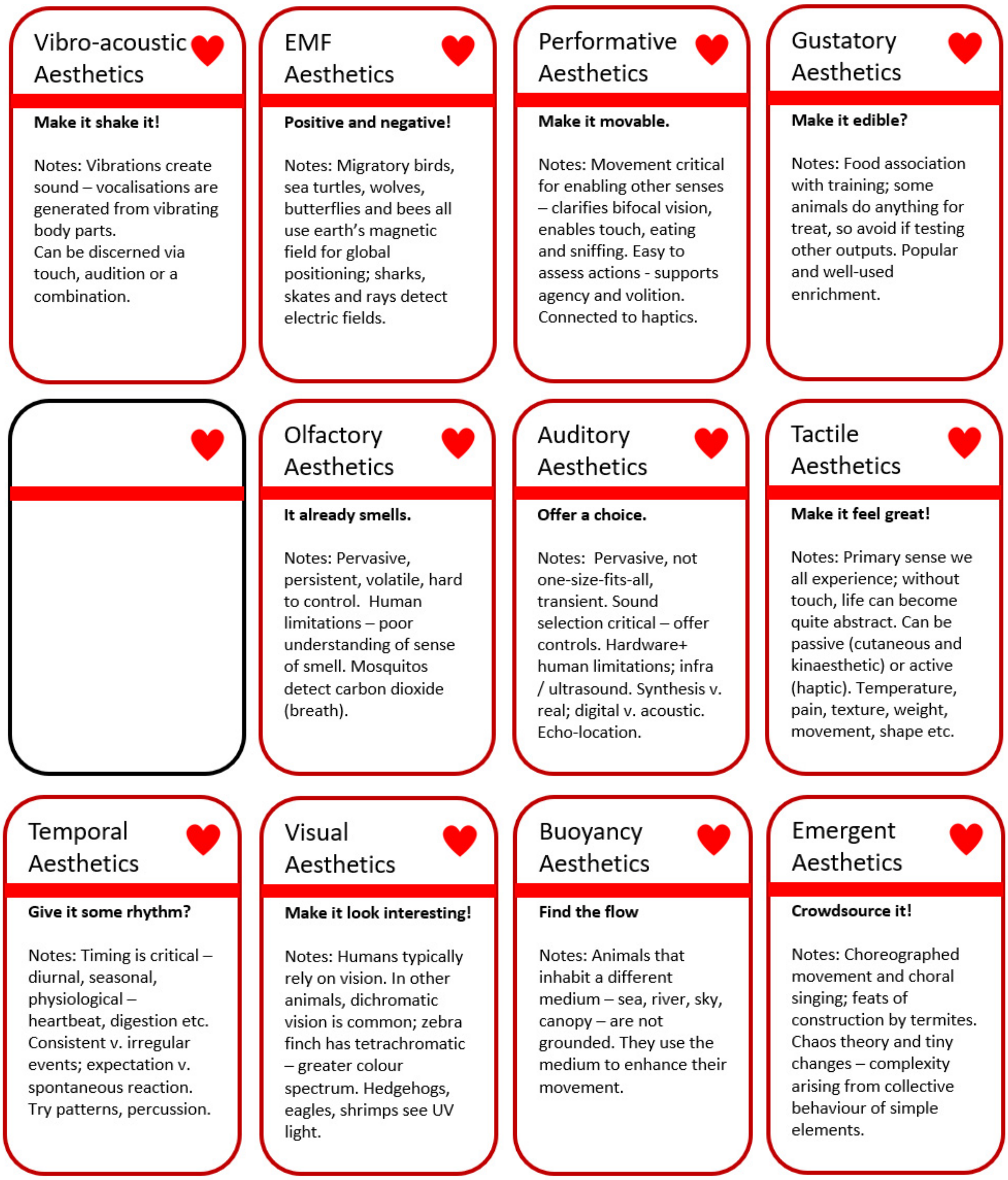
(ii) Species Characteristics

A team of designers might aggregate existing knowledge about *Species Characteristics*, or research unknown dimensions. In our case, the contrast between **wild** and **captive** lifestyle was important, in that it gave rise to our enrichment goals; in addition, since we were often working with an **individual** elephant user, it made sense to recognize and take account of her particular characteristics and preferences. The other characteristics – **emotional**, **cognitive, sensory** and **physical** – are all important for designers to understand so they can appreciate their users, whatever the species.



(iii) Aesthetics

We have emphasized the importance of aesthetics and explained which aesthetic dimensions we explored the most in our work – **tactile** and **auditory**. While each species will have its own favoured modes of perception and associated aesthetics, we suggest that **performative** aesthetics has a strong potential to engage an animal and moreover, afford a good sense of control.



We have included aesthetic dimensions that are not perceptible to humans without technological tools so that the set is less anthropogenically focused; some of these dimensions can only be imagined by humans. An example of this is **EMF (Electro-Magnetic Field)** aesthetics, which relate to a phenomenon that humans seem not to be able to perceive. There is increasing evidence that a wide range of animals can detect and utilize electro-magnetic fields, to determine location and direction, and to detect prey and predators and mates. Animals sensitive to these signals can discern tiny changes in intensity or direction (Hutchison et al., 2020) which means that any interference (such as anthropogenic noise pollution) can have a profound effect. Although the aesthetics cards are intended to highlight potentially positive design features, they also serve to warn against *masking* existing sensory experiences that may contribute to pleasure or fitness.

Another sensory experience that may be hard for humans to fully appreciate is the combined control and freedom of movement associated with traversing a medium that offers an upward force to counteract gravity – we describe this as **buoyancy** aesthetics for those that are expert fliers, swimmers and swingers. These animals have evolved to be able to move through air and water with minimum effort and maximum effect. To human observers, there seems to be joy inherent in this activity, to the extent that we have historically tried to emulate the effects.

Emergence is a phenomenon that occurs within a system composed of multiple entities that act independently yet cause a complex behaviour to occur. Examples include swarming (e.g. murmuration of starlings) and co-building structures (e.g. termite mounds). Emergent behaviour has evolved to benefit both the individuals and the species. It seems clear that there are aesthetic dimensions associated with being part of, and contributing towards, a bigger system. Collective behaviour, on the other hand, is driven by group dynamics and emerges spontaneously, often violating normal behaviour.

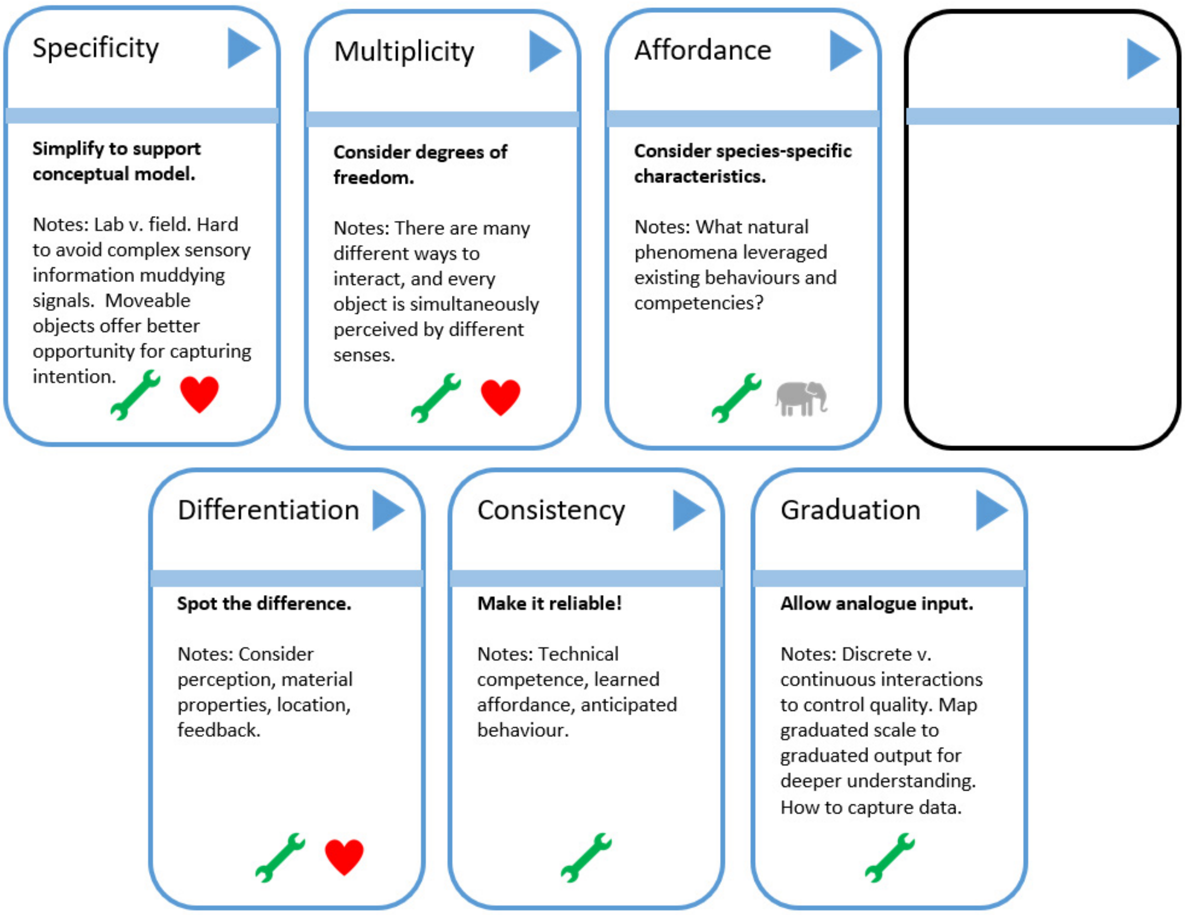
We acknowledge that there are some overlaps between cards – for example **auditory**, **vibro-acoustic** and **tactile** aesthetics. While there is an argument that these cards could be combined into one, we feel it is likely to provoke more discussion around the topic if they are presented separately. There is also a clear link between **tactile** and **performative** aesthetics via haptics and kinaesthetics, although descriptions of touch usually distinguish between cutaneous, kinaesthetic and haptic sensory information.

Temporal aesthetics has many facets. As well as relating to rhythms, there is a connection between time and olfaction for animals with a good sense of smell, such as elephants, dogs and bears. Because humans primarily rely on vision, we perceive what is around us *at the moment.* Although our memories and imagination let us traverse time fluidly backwards and forwards, our olfactory limitations require us to live in the present with respect to our immediate perceptions. Dogs, on the other hand, inhabit a world of layered timelines, whereby their noses provide them with complex information about the history of the environment. Scents dissipate over time, so the intensity of a smell is a clue to its age.

(iv) Interaction

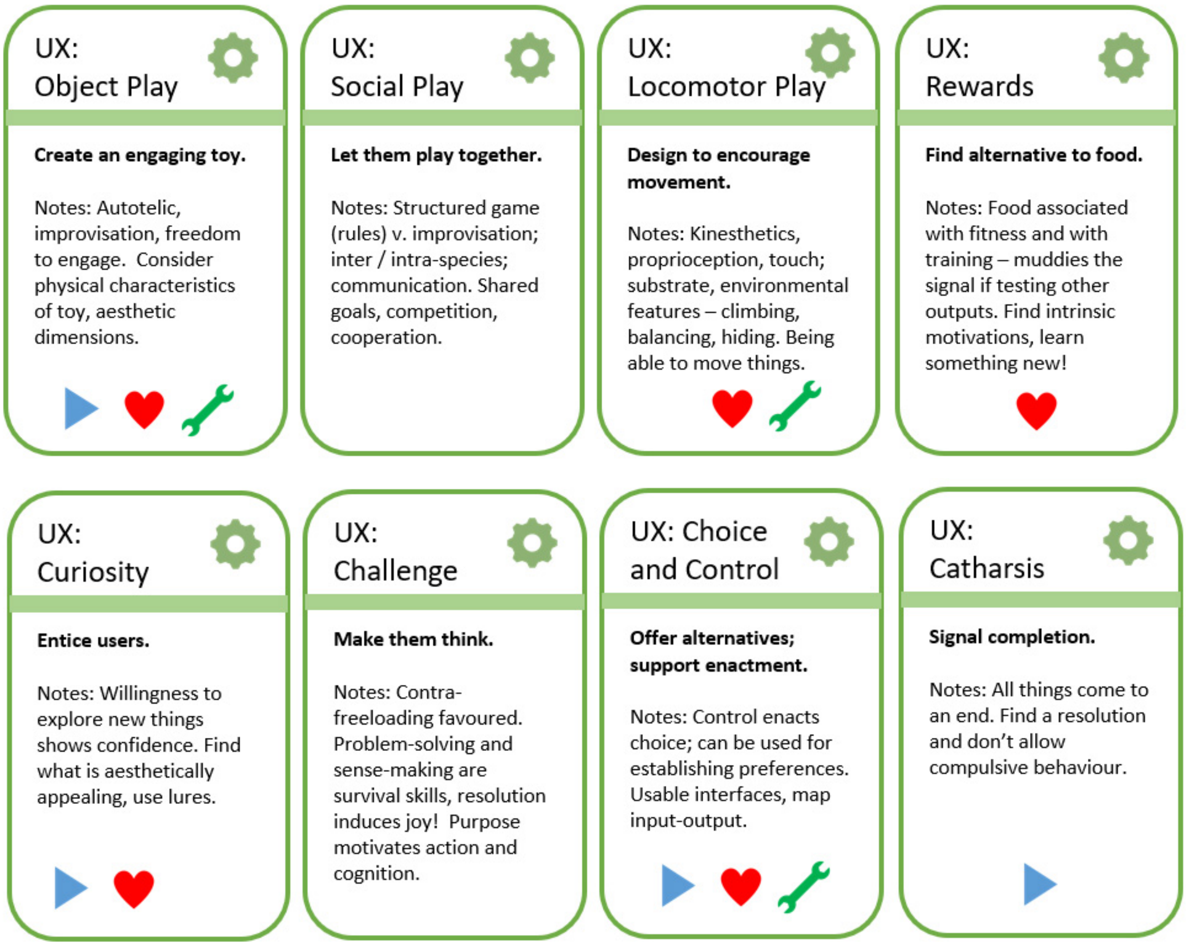
In this set of cards, **differentiation**, **consistency** and **graduation** are design features of the system that directly benefit the user, enabling them to make sense of an interface and its relationship with the system, as well as supporting choice and control. **Specificity** means trying to ensure that a *specific* interaction on the part of the animal causes a *specific* output; it therefore relates to designer understanding of the animal user's intention and is a difficult feature to implement successfully outside laboratory conditions. **Multiplicity**, on the other hand, reminds us that there are many possible relationships that an animal can have with a system, opening up the question of degrees of freedom. This card suggests to designers that the designed object may have many more sensory characteristics than humans can identify, and it may therefore be challenging to determine an animal's intention when she selects and manipulates a control.

All these cards have a relationship with the concept of **affordance** and build on this fundamental design principle, initially mentioned in *Section 5.2 Understanding Elephants* (Chapter 5: Design and Craft), in relation to the work of Norman (2013), and further developed in *Section 6.2 Interaction Design for Elephants* (Chapter 7: Reflections on Design and Craft).

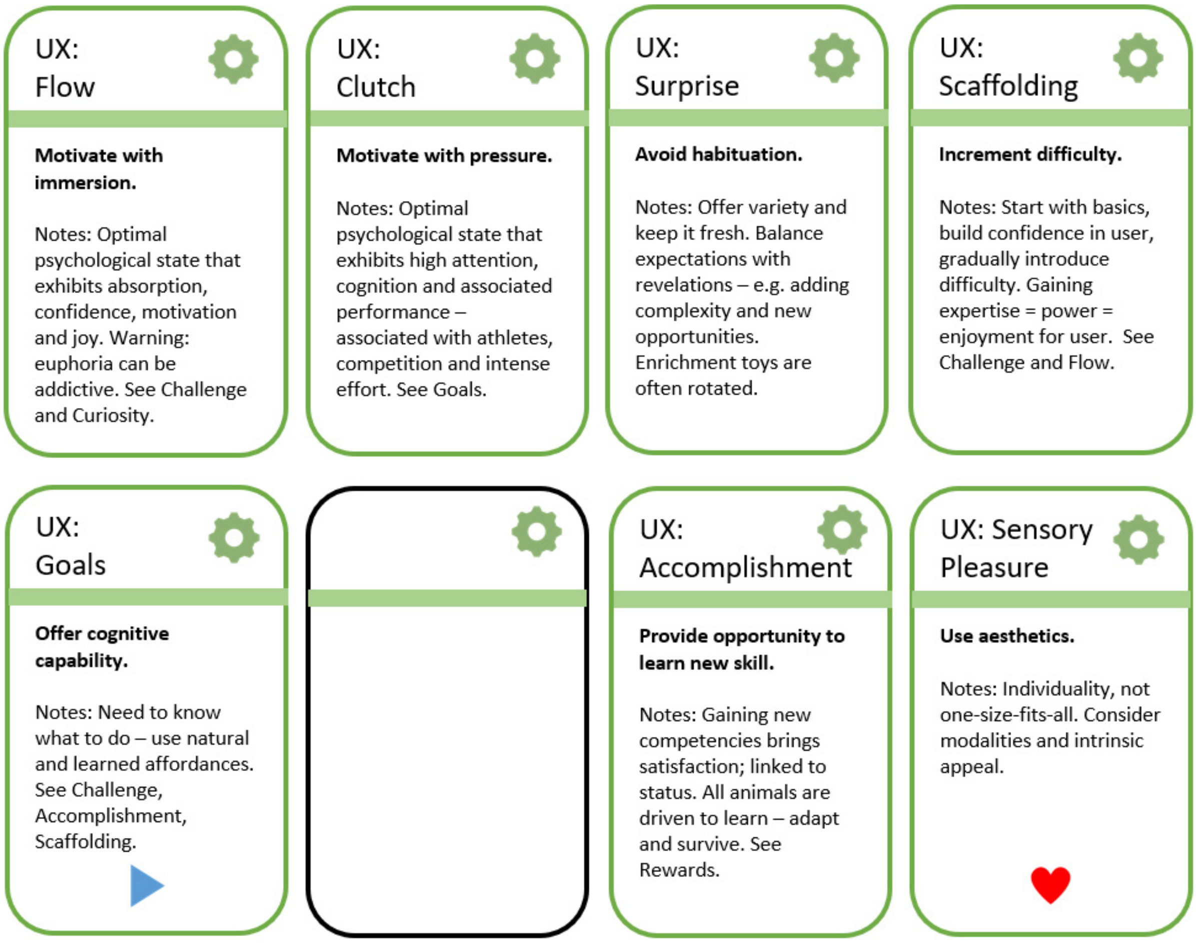


(v) Experience Design

The *Experience Design* cards offer an abstract overview of possible directions that designers might wish to explore in order to provide engaging systems for different species, and we would suggest that they are considered in conjunction with the goals that have been established for the project. A ZooJam would fit well at this stage of development. Some of these concepts are well established as motivational aspects of game design – **challenge**, **control**, **curiosity**, **catharsis**, **rewards**, **scaffolding**, **sensory pleasure** (Malone & Lepper, 1987; Crawford, 1984; Costikyan, 2005). Some have been taken directly from literature on animal play – **object** and **social play** (Young, 2003). Others are derived from recent research on enrichment and gamification – **surprise** and **accomplishment** (Coe, 2017; Chou, 2015).



The concepts we used to develop prototypes for Valli were related to cognitive enrichment – challenge, choice and control, curiosity, surprise – and to sensory enrichment – rewards and sensory pleasure. We attempted to encapsulate these experience motivators in the context of an object, with an emphasis on **locomotor play**, which is a quintessential aspect of almost all animal play. Locomotor play is the recognized term for physical play that involves large body movements, of the type that might encouraged by providing a climbing frame. In this card set, we emphasise this as a key consideration for designers, linking it to (performative) aesthetics.



Flow has long been associated with the particular mindset that some games can engender in players – characterized as an optimal experience that exhibits high levels of focus and enjoyment (Csikszentmihalyi et al., 2002). For game designers, inducing a state of flow has often been seen as the ultimate challenge, summarized by Salen and Zimmerman as a call to "*design meaningful play*" (Salen & Zimmerman p.337-338). Although this sounds like a positive objective, there may be ethical issues associated with manipulating players, both human and non-human, so that they invest a large proportion of their time on a designed activity.

Recently, another optimal psychological state has been defined – **clutch**. This is also associated with heightened concentration and performance, most commonly in respect to athletes. In comparing the two states amongst people exercising, Swann et al. comment: "*Flow occurred in contexts involving exploration, novelty/variation, and flexible outcomes, while the experience was described as enjoyable at the time and involved lower perceived effort. Clutch states occurred in contexts involving achievement and pressure. Exercisers perceived clutch states to be enjoyable afterwards but not at* *the time, and to involve intense effort."* (Swann et al., 2019) They also found that experiencing flow was ultimately energizing, whereas clutch gave rise to fatigue. Both these experiences may be valid for non-human animals engaging with a novel system, depending on the behavioural goal that has been defined.

(vi) Craft and Tinker

Everything physical that the designer might want to happen is represented in this set of cards. These are topics that enabled the production of prototypes and often required us to make technical design decisions. They are typically areas where an exploratory approach can yield useful outcomes.

We have highlighted topics that require knowledge of electronics, using this symbol:

Input

Tinker inputs.

Notes: Lab v. field – sensors always need recalibrating under different conditions. Environmental effects – metals, humidity, light level etc. Use prosthetic – see **Templates**.

Output

Tinker outputs.

Notes: Map input-output to explore preferences. Some outputs can be synthesised (e.g. audio, haptic).

Power

Check power consumption.

Notes: Some sensors and networked devices on constantly. Low voltage prototypes typically use batteries, may need changing.

Networks

Manage networks.

Notes: Critical for reliable data capture, remote control, surveillance, webcams, communication and sharing data across devices.

Material Dimensions

Choose materials with care.

Notes: Sensory and cognitive awareness, appreciation of aesthetics. For example, scale, shape, texture, plasticity, smell, colour, weight.

Safety

Run a safety check.

Notes: Critical; artefact must be robust, non-toxic materials, embedded tech – no loose wires, fixed securely – see **Fittings**.

Fittings

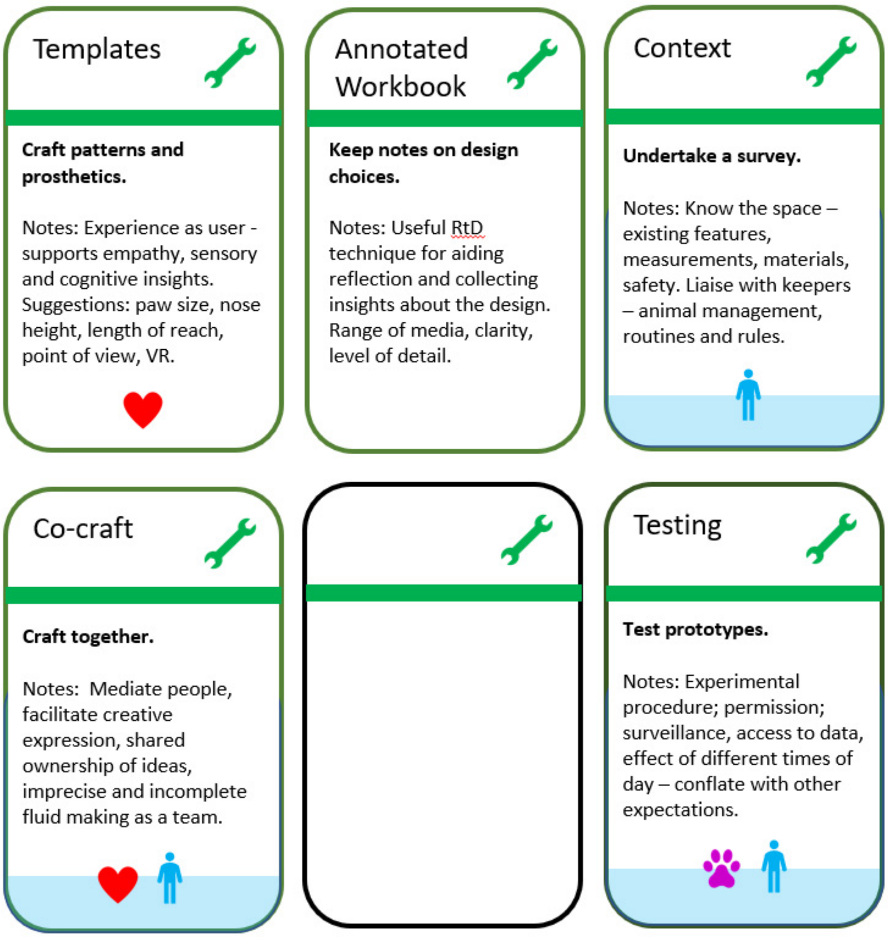
Check environment.

Notes: Critical for deployment, need to be portable, demountable, easy fix and change. Consider integrity of building, cost and safety – see **Context**.

KISS

Keep It Simple.

Notes: Supports sharing – easy to maintain and co-craft; scope, feasibility – cheap to make, speed – good for quick prototypes.



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Through our card sets, we acknowledge the conceptual overlaps between areas, while attempting to frame the theory in discrete collections of topics.

The following section presents two fictional scenarios that illustrate how the deck might be used by different teams of designers at different stages in their projects. These scenarios were particularly useful in supporting the evolution of the cards by imagining how different groups of developers might want to use them.

The first is based around an idea that was actually generated during the first ZooJam, in 2016, in response to a brief by a sea lion keeper from London Zoo. The imaginary team have already established enrichment goals and have a rough concept, so they are starting from a point where they need to collaborate with each other to firm up the design. The second scenario is entirely fictitious and sets the scene at a later stage in an imaginary project; early prototypes have been tested unsuccessfully and the cards are being used as tools to support troubleshooting during the production/crafting stage.

This section describing scenarios is followed by Section 7.4 Evaluation of Concept Craft Cards, which describes an early opportunity we had to evaluate the deck of cards, through taking part in a technical demonstration. We also explain some future ideas for evaluation.

7.3 Scenarios with Concept Craft Cards

7.3.1 Hunting Enrichment

London Zoo have been given extra funds and are keen to move forward with a plan to introduce hunting enrichment for their sea lions. Ideas were originally conceived at the 2016 ZooJam, but none of these made it into production. Keeper Kirsty calls a virtual meeting with ZSL Project Manager Malcolm, ACI Designer Dwaine and ACI Engineer Elizabeth.

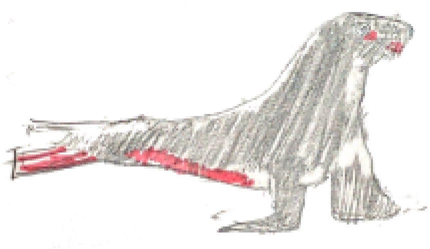


Figure 34: Sea lion sketch

Dwaine suggests that everyone has a look at the **Concept Craft Cards** prior to the meeting, so there are some clear discussion points. Kirsty prepares an agenda – 1. Introductions, 2. Discuss proposals, 3. Actions moving forward.

Figure 35: Key Values cards

The team looks at the **Key Values** cards on Dwaine's screen-share.

Kirsty clarifies the enrichment goals mentioned on the **Focus** card: (i) to promote natural foraging behavior; (ii) to increase time spent foraging; (iii) to reduce keeper focus for food. Elizabeth suggests there will be technical goals and Dwaine says there will be interaction design research opportunities that the team should consider. Malcolm points out that there will need to be a clear financial trail to show how the funds have been allocated. With regard to **Ethics**, the team agrees that using natural and eco-friendly materials is important and aligns with ZSL values; Dwaine suggests that community involvement might be useful if visitors could take part in the enrichment and photograph themselves for social media (thereby providing a free marketing campaign).

Elizabeth: *__Empathy__ cards link to __Species Characteristics__ and __Aesthetics__. You're the sea lion expert, Kirsty, but it will help us as designers if we also understand the animals as much as possible. Can we arrange to visit the zoo and do some observations?*

Dwaine: *We also need to undertake a survey of the enclosure and find out about your schedules.*

Kirsty: *Sure, I'll send you some links to stuff about sea lions and you can ask me questions when we meet. Which cards shall we talk about next, Dwaine?*

Malcolm: *Hang on, I didn't have time to look at all the cards. What does the paw signify?*

Dwaine: *That means we need to collaborate with the animal in order to understand the topic properly. And other people, of course. Like you. Shall we skip **Characteristics** for now and move on to **Experience Design**?*

Malcolm: *I thought there was already a plan for a bubble toy? Kirsty?*

Kirsty: *That's right. But we also had ideas for fish cannons and lazy rivers and remote-controlled lights in the walls…*

Malcolm: *We don't have funds to make expensive alterations to the pool.*

Kirsty: *I know, but I'm not convinced that a bubble toy would meet our goals.*

Elizabeth: *Let's talk about how it might work.*

The team looks at the **Experience Design (UX)** cards while they discuss the bubble toy idea, which involves releasing fishy air bubbles into the water at intervals, so that the sea lions will chase them.

Figure 36: UX cards (i)

First of all, they mention that the toy concept is smelly, noisy and visual, and probably also tactile since the sea lions could feel the bubbles with their whiskers or noses. So, it provides a lot of different **sensory stimulation**, and is very likely to attract the animals' attention – **Curiosity** – check. In addition, since the whole point of the exercise is to promote hunting behaviour, it makes sense for the **Reward** to be food, and receiving a good meal at the end is the obvious **Catharsis**.

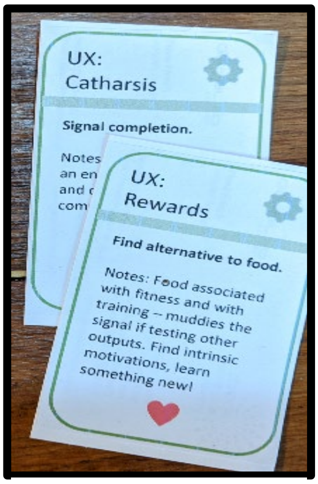


Figure 37: UX cards (ii)

The other **Experience Design** cards generate more discussion.

Dwaine: *How do you envisage it working, Kirsty?*

Kirsty: *We want to stimulate exercise, so the sea lions will have to work hard before the reward is triggered. We'd need a few bubble toys around the perimeter, and after they have done a lot of chasing, the cannon fires a bunch of fish into the water.*

Elizabeth: *So, the system has to keep track of how many times the bubbles are released, or how many times the sea lions catch them?*

Kirsty: *Yes, we don't want a keeper to be doing it at the same time every day.*

Malcolm: *But the sea lion training sessions are very popular with visitors.*

Kirsty: *They are indeed. This could be an additional feature, though. One that's not as predictable.*

Dwaine: *How can the system offer the sea lions **choice and control**?*

Figure 38: UX cards (iii)

Controlling the system brings up a lot of new ideas relating to interface designs that enable sea lions to trigger outputs. Instead of the system randomly releasing bubbles at intervals, the team thinks that the sea lions might be able to activate the bubble toy themselves using a 'button', which might even be on land. They wouldn't know which bubble toy was going to release fishy air next, so they'd need to pay attention to the water and race to reach it.

There are still many unanswered questions relating to the functionality of the system and how to implement a suitable interface for sea lions, but now everyone in the team is starting to appreciate the complexity of the **challenge** – for the sea lions and for themselves! Malcolm thinks the visitors would be fascinated to watch sea lions setting off the bubble toys; Kirsty is excited at the prospect of trying out new enrichment devices with the animals; Dwaine is thinking about interface designs; Elizabeth is trying to figure out the simplest way to install remote-controlled bubble emitters underwater…

The team members have a lot to think about before their face-to-face meeting at the zoo.

* * * * * *

When the team meets later at the sea lion enclosure, everyone has made some time to look at the cards again. After reading the **Craft** cards, the zoo staff are beginning to understand all the work that will go into the development of the enrichment solution and can now see opportunities to become more involved by offering advice and suggestions. They discuss suitable places for fitting devices; they explain some of the animals' personalities and how this could impact on their behaviour; they begin to search for clean plastic containers that can be repurposed as bubble dispensers. Dwaine and Elizabeth take lots of photos and video, do a rough survey, watch a sea lion training session and listen carefully to everyone's ideas.

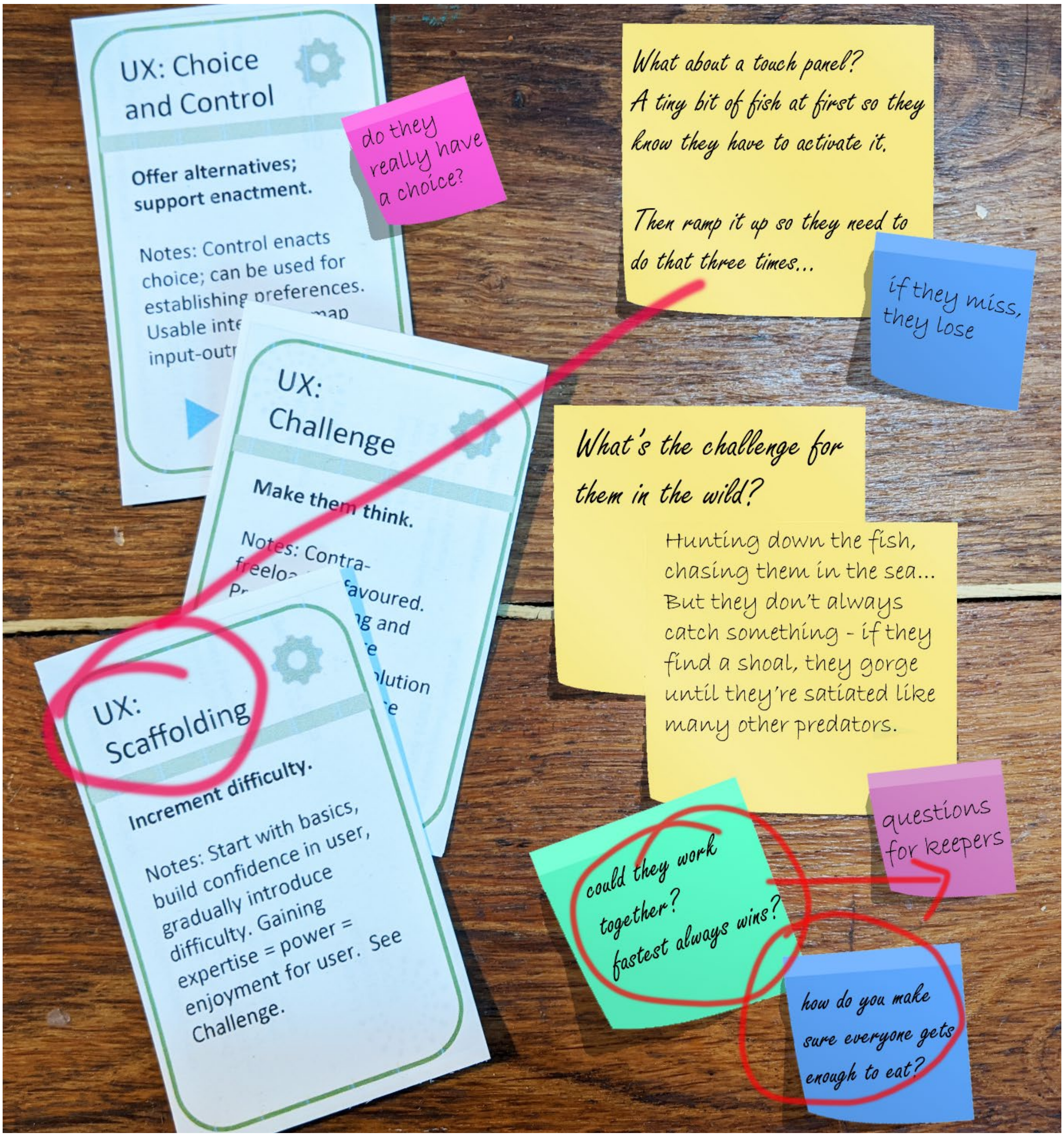


Figure 39: Talking together around the table

A new discussion about water pressure and pipe dimensions that will accommodate dead fish is initiated by Elizabeth. Let's leave them there…

7.3.2 PrefMat for Pets Research Project

ACI researchers Jane and John have been working on a feedback system for companion animals that enables them to express their preferences to their humans in a more nuanced fashion than usual.

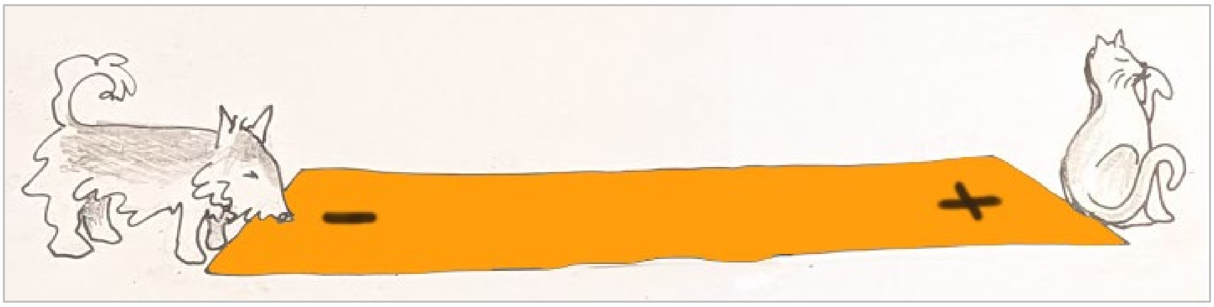


Figure 40: Tufty and Caligula with a PrefMat

The system (tentatively called a PrefMat) will be installed inside each household's shared living accommodation. It consists of a long plastic mat on the floor, which is sensitive to pressure along its length. One end represents positive and the other negative, with graduation in the middle. When a pressure point is triggered, the system outputs a small beep sound. The researchers hope to train Jane's cat Caligula and John's dog Tufty to use the device to determine the animals' preferences in regard to treats and shared activities, for example (but not at the same time).

Since Caligula is such a fussy eater, Jane already knows what dishes he prefers, and she has devised a training plan which she has already started. Before she puts poached salmon (his favourite) in his bowl, she consistently places him on the positive end of the mat in her house. Before she gives him supermarket brand cat kibble, she places him on the negative end. Sardines, cheese, blueberries and boiled eggs are somewhere in the middle.

John, meanwhile, believes that because Tufty watches him so closely, she will be able to learn how the system works if John shows her by using it himself. When Tufty comes to greet him, wagging her tail, John always goes to sit on the positive end of their mat and gives her a pat. If Tufty hears a noise in the night and starts barking, John gets out of bed and sits on the negative end; unfortunately, he then often falls asleep on the floor.

Despite a promising early start, when Jane and John hacked an old dance mat, hooked it up to a laptop and reliably captured nine different pressure points, working with the animals is proving to be challenging. In Jane's house, the PrefMat is placed in the hallway. Caligula makes a point of avoiding it, carefully sidestepping the device on his way to and from the door. In John's house, the PrefMat is located behind the sofa, but Tufty has shown no inclination to use it yet. Jane and John decide to have a look at the **Concept Craft Cards** to see if that gives them any fresh insights.

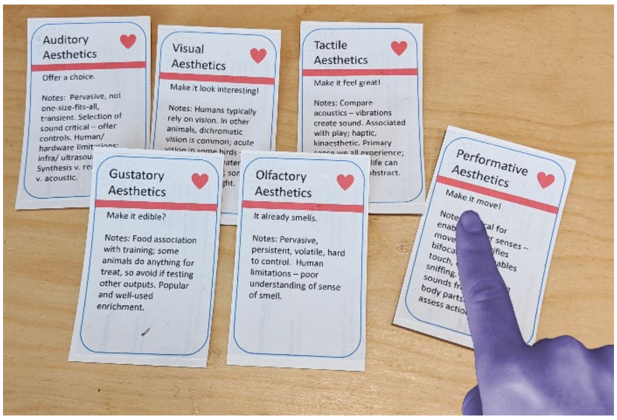


Figure 41: Looking at the Aesthetics set

They have already established their **Focus** and share **Ethical Values**; they each have strong relationships with the test subjects and feel they have **Empathy** with their companion animals. So, they have a look at the **Aesthetics** card set in relation to the PrefMat and immediately realise that the **smell** and **feel** of the plastic (from the original dance mat) might not be very appealing to Caligula and Tufty. Moreover, the animals may not like the beep **sound**, which has no meaning for them as it bears no relation to their choice. In fact, using a single beep was a deliberate decision by the designers, John and Jane, because they didn't want the sound to influence the place where the mat was triggered, but they did want a convenient human alert so they knew whether Caligula and Tufty were engaging with the PrefMat while they weren't watching. Now it seems that might have been counterproductive. Jane and John move on to the **Craft** and **Interaction** sets and lay out the cards.

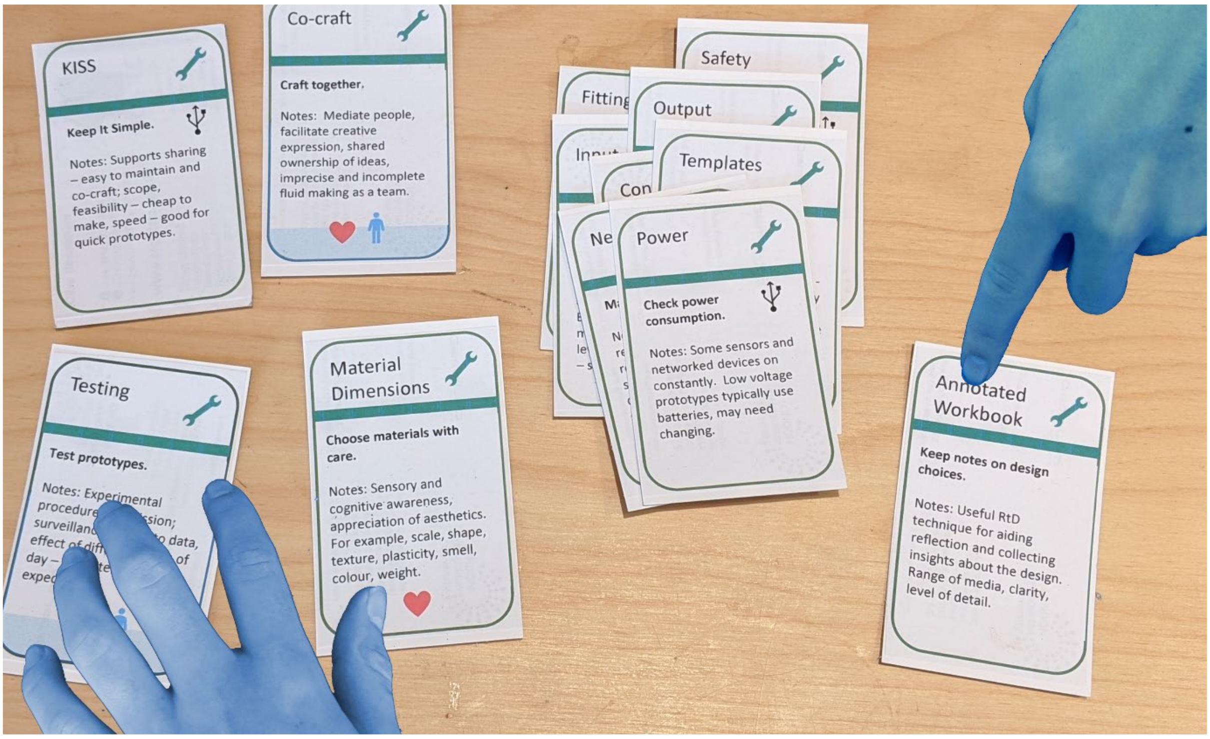


Figure 42: Looking at the Craft & Tinker set

John: ***Material Dimensions*** *again. That links with the* ***Aesthetics****, doesn't it? I wonder if the same thing will work for both cats and dogs? We've done a lot of* ***Co-crafting*** *and that was useful. But maybe we should experiment individually for a bit, and then compare notes.*

Jane: *Sure. We're going to need a few versions of this mat, I reckon.*

John: *Yes. I like this* ***Annotated Workbook*** *idea. I think we should try and do that. It could really help us.*

Jane: *I might cover the mat with some soft blanket and switch off the beep. I can still extract the data and the times Caligula uses it.*

John: *You know, I'm quite interested in the* ***performative*** *aspect for Tufty. I'm not sure she'll engage with a mat…*

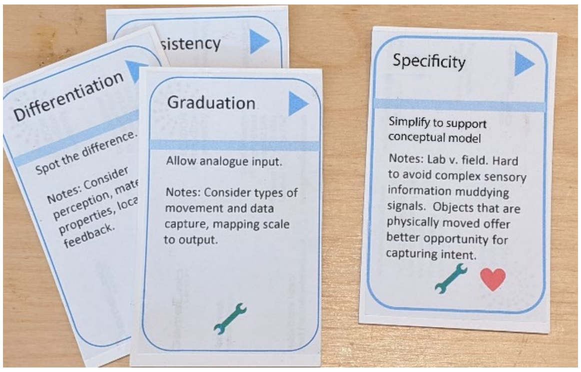


Figure 43: Looking at the Interaction set

Jane covers the PrefMat with soft material and finds that Caligula curls up on the positive (poached salmon) end regularly. However, Jane notices that this end is also closer to the hall radiator. She understands how difficult it will be to create an unbiased system and starts to wonder if a **moving** input device would be more appropriate for the cat as well, since he would have to actively choose to manipulate it and it would then be easier to determine his intention.

John tries to think of physically moving systems that will enable Tufty to make a clear **graduated** response. He recognizes that tinkering with the **inputs** and **outputs** is going to be critical before they have a working solution. It's time to go back to the drawing board with Jane, but first he will take photographs of the existing system and update his design notes…

7.4 Evaluation of Concept Craft Cards

An early test of the cards' potential to stimulate discussion was carried out at the Creativity and Cognition conference (https://cc.acm.org/2021/) in June 2021, as part of a virtual technical demonstration (French et al., 2021). The virtual conference was held in a Gathertown (https://gather.town/) environment, augmented by a dedicated Slack (https://slack.com/intl/en-gb/) workspace. Gathertown provides live audio and video streaming with the opportunity for people to move around the venue and join in conversations based on their avatar's proximity, while Slack offers a set of channels for subsequent text interactions.

In our demo, visitors were invited to take part in three design challenges, using the cards to support their concept generation:

1. CHALLENGE: Toys for kenneled dogs at Battersea Dogs and Cats Home.
2. CHALLENGE: Cognitive and social stimulation for house-bound elderly.
3. CHALLENGE: Enrichment for captive elephants.

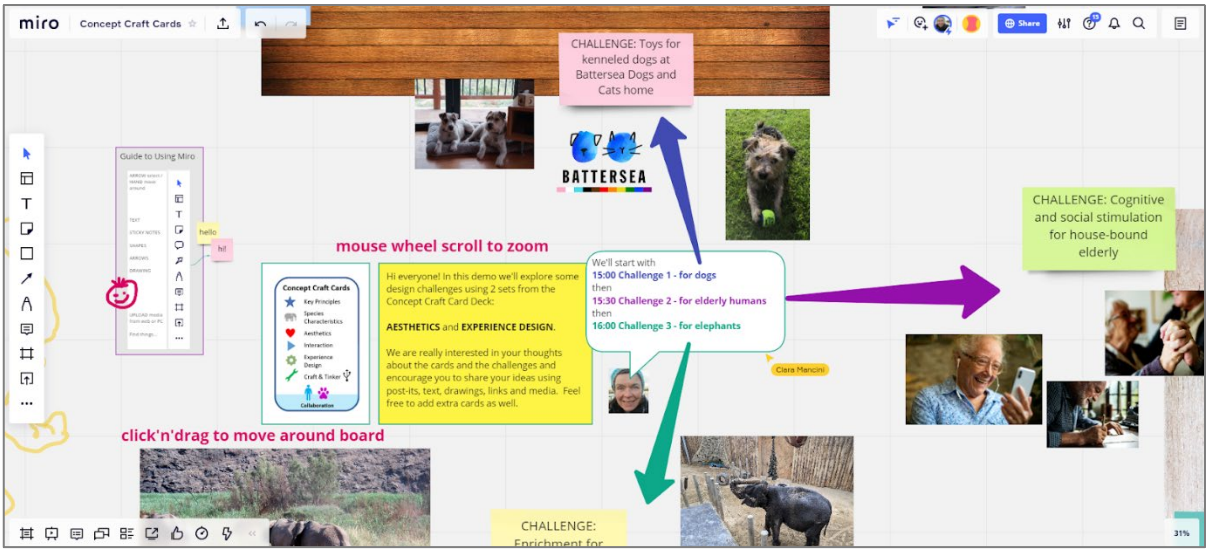


Figure 44: Miro Board showing start screen

Challenge 1 was chosen because we thought many participants would be sufficiently familiar with dogs that we could avoid a lengthy discussion of their particular species characteristics and move swiftly on to some ideation. Challenge 2 was chosen to emphasise humans as another species of animal and to explore what relevance (if any) the deck has for HCI and designing for people. Challenge 3 was chosen because of our background knowledge of elephants and consequent ability to answer questions and offer feedback.

The demo was visualized using a Miro interactive whiteboard, embedded in a Gathertown room (see Figure 44). We set up three empty tables, one for each challenge, and provided 2 sets of cards (Aesthetics and Experience Design) for each table, as well as some questions relating to the topic and some empty post-it notes. We chatted to visitors and encouraged them to explore the demo space, move cards around and add their own notes and media. We knew that participation in our tech demo was likely to be asynchronous, since although it was given a dedicated timeslot it was running simultaneously with other demos and posters. We therefore avoided any tightly structured activities that would require people to work in teams.

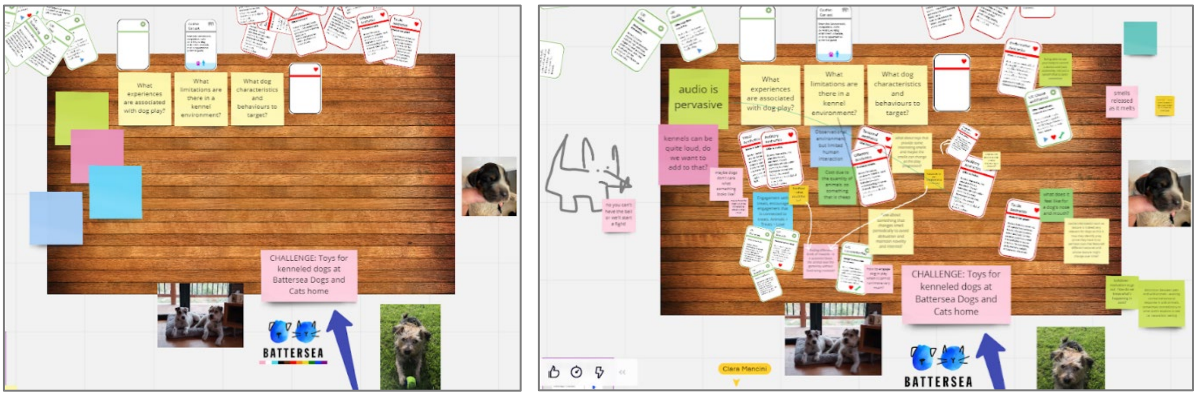


Figure 45: Dog challenge table before and after demo session

Figure 45 shows the activity around the dog challenge table in Miro, where visitors selected specific cards to use, added ideas and comments and made links between items. Interestingly, people also started to make links between the tables (see Figure 46).

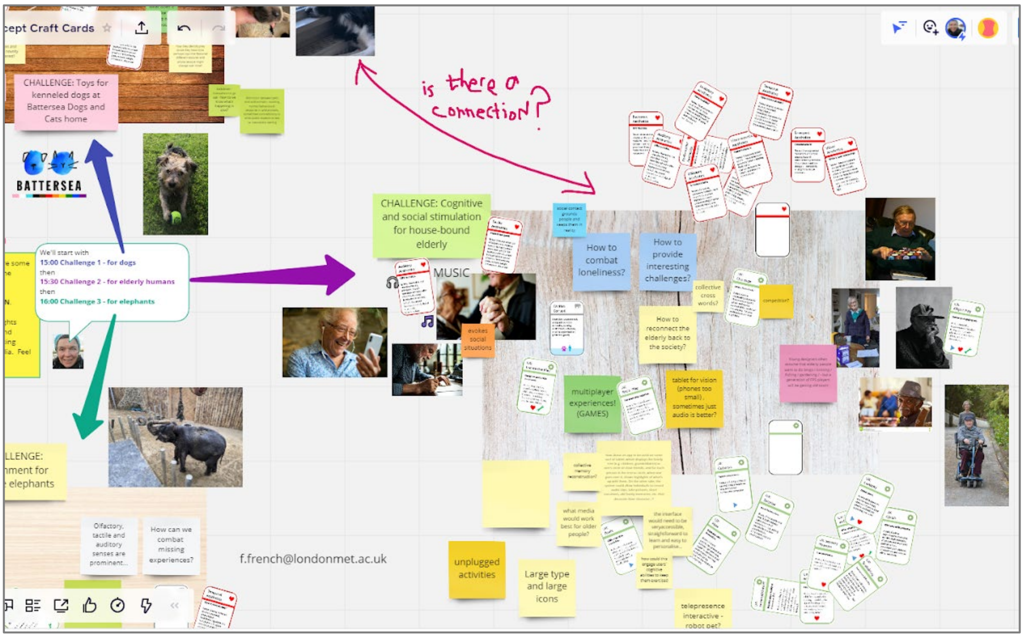


Figure 46: Elderly challenge table after demo session

Written outputs (post-it and text) from the dog challenge table, linked to cards that were deployed:

- Captive Lifestyle / Context
  Observational environment but limited human interaction. Cost due to the quantity of animals, so something that is cheap. Lockdown – motivation to go out – how do we know what's happening in zoos? Distinction between pets and wild animals – evoking normal behavioural response in wild animals, sometimes contradictory to what public expects to see i.e. naturalistic setting.
- Visual Aesthetics
  Maybe dogs don't care what something looks like? Maybe focus for dogs would be more tactile / olfactory than visual.
- Auditory Aesthetics
  Audio is pervasive. Kennels can be quite loud, do we want to add to that? What sounds good to a dog? What is disressing v. pleasant?
- Olfactory Aesthetics
  What about some toys that provide some interesting smells and maybe the smell can change as the play progresses? Adaptable for pet characteristics – likes vary. I wonder… short term flavour i.e. like a tactile item with flavour like a lolly pop. Smells released as it melts.
- Tactile Aesthetics
  What does it feel like for a dog's mouth and nose? Tactile information such as texture is indeed very relevant for dogs as this is how they identify prey (once they have it) so perhaps toys that featured different textures and whose texture might change over time?
- Performative Aesthetics / UX: Choice and Control
  Being able to use your body to co ntrol a device and have autonomy, not just a system that is carer-controlled.
- UX: Rewards
  Not food – what could this be? Finding different kinds of rewards – is it autotelic? Does the animal love the game/toy without food being involved?
- UX: Locomotor Play
  How to engage dog in play when it cannot run/move very much? No you can't have the ball or we'll start a fight!

Written outputs (post-its and text) from the elderly challenge table, linked to cards deployed:

- Auditory Aesthetics / Tactile Aesthetics
  (Music) evokes social situations. Social contact grounds people and keeps them in reality. Tablet for vision (phones too small), sometimes just audio is better?
- UX: Social Play
  Multiplayer experiences! (Games) How about an app to be used on some sort of tablet, which displays the family tree (e.g. children, grandchildren) or one's circle of close friends, and for each person in the tree or circle, when one goes over it, shows highlights of what's up with them. On the other side, the system could allow individuals to record audio clips, take pictures, short narratives, old family memories, etc. that decorate their character...? Collective memory reconstruction? The interface would need to be very accessible, straightforward to learn and easy to personalize. Telepresence interactive – robot pet?
- UX: Challenge / UX: Goals
  Collective crosswords. Competition? How to reconnect the elderly back to the society? Young designers often assume that elderly people want to do bingo / knitting / fishing / gardening / but a generation of FPS players will be getting old soon! How could this engage users' cognitive abilities to keep them exercised? Large type and large icons. Unplugged activities.

By the time we progressed to the elephant challenge, fewer people were involved and most of the ideas were expressed verbally, so this part of the board has fewer interesting comments written down.

During informal discussions with users, to discover their thoughts about the card deck, the *medium* (Miro collaborative whiteboard) and the *mode of engagement* (free association and relatively unstructured activity) were mentioned in conjunction with the cards themselves. One participant commented: "*It is good to co-locate all groups in one space, so people can make connections between ideas and tables…*" In general, the session seemed very creative and free-flowing, less structured than if we had used the templates (that Miro provides) but richer and more engaging because people could find their own space on the board and expand this to make room for their thoughts. We were trying to replicate virtually an activity that usually takes place in real life, around a table, and in this regard, we believe we were successful, even though participants came and went at different times. (Note that we have accomplished this several times before in the context of longer events.) The cards certainly generated discussion amongst participants and presenters, as well as offering some scaffolding for ideation. We would also like to draw attention to the similarity between the speculative collaboration suggested by our scenario mock-ups (e.g. Figure 39) and the actual collaboration shown in the Miro screenshots (e.g. Figures 45 and 46).

As a result of running the demo, we have had requests for copies of the cards from some of our participants who are planning to develop new projects, including a team of interaction designers working with a US zoo and a research lab that focuses on expressive computational tools for art, design and engineering. We look forward to receiving their feedback in due course.

7.4.1 Future evaluation

In their analysis of card decks as design tools, which drew positive conclusions regarding the effectiveness of cards in this context, Roy and Warren (2019) point out that few decks have been tested independently; most are only tested by their developers. Peters et al. (2020) undertook a similar analysis, encompassing a wider range of physical design tools that included toys and board games. They suggest a novel taxonomy for physical design tools, with seven categories; our deck seems to fit into several of these, including prompts, components, construction and methods. Moving forward, we may incorporate some of these insights into our strategy for sharing and evaluating the Concept Craft Card deck.

We plan to share the card deck with members of the ACI community, asking people to use them in their projects and subsequently provide feedback and suggestions for development. We will also use the cards in a future workshop setting, as part of a scheduled activity session. We hope to organize another ZooJam event focusing on the design of novel enrichment. In this ZooJam, we would use specific sets of cards (such as Aesthetics) to guide participants' creative exposition and encourage reflection on the details of their design choices.

Our work shares some common goals with Hook's Interspecies Design Toolkit (https://www.interspeciesdesign.co.uk/interspecies-toolkit/), which is available online and includes a set of Interspecies Design Activity Cards that facilitate designers to gain a less anthropocentric perspective on their potential users. We are also developing activities around the Concept Craft Cards, aiming to draw together workshop participants in shared practice and reflection. Hook defines three guidelines that he names '*Principles of Interspecies Design'* in the toolkit: (i) Recognise exclusion; (ii) Learn from other species; (iii) Design with one, speculate for many. The first principle highlights the need to embrace an inclusive attitude when designing for non-human species who have different biases and abilities from our own. This is a theme we address directly with our *Species Characteristics* and *Aesthetics* card sets. His second principle reminds us that humans are experts at being flexible, and that we should be the ones to adapt rather than the non-human animals who share our world space. This is also a point made by French et al. in their recent paper on ethics and power dynamics in tech for animals (French et al., 2021) and is reflected in the *Key Value* card *Empathy*, which underpins all our work. Finally, Hook's call for particularity and a speculative design approach resonates with our own RtD work ethic, which valued a bespoke solution for one elephant in order to gain insight into designing for the species, and indeed designing for any non-human species.

The Interspecies Design website is very accessible with beautiful graphics, inviting visitors to consider its themes from a theoretical viewpoint, despite Hook's work being grounded in both design and craft (Hook, 2019). By contrast, we have endeavoured to share practical insights that designers can select and adapt for their own purposes, making our contribution less didactic and potentially offering more collaborative potential. The strength of our deck is perhaps in its incompleteness, which invites authorship, and in its fluidity as a collection of discrete and moveable items that humans are tempted to arrange into patterns to show different relationships.

7.5 Summary

We have chosen to present our key contributions using a physical ideation and prototyping tool - a deck of **Concept Craft Cards**. The practicality of the cards, aligned with their collaborative potential, fits well with our **Research through Design and Craft** methodology.

Co-crafting was an important part of the **ZooJam** workshops we organised, facilitating collaboration between participants and the sharing of ideas, as well as helping teams to focus on physical aspects of their designs.

Crafting has empowered us to uncover aesthetic elements that are relevant to the elephants we worked with, and potentially to a wider elephant audience. Fundamentally, our exploration enabled us to develop aesthetic sensibilities that a human-centred perspective might fail to appreciate but that **more-than-human-centred** design demands. We specifically note the strong link between **performative and sensory aesthetics**, whereby *doing* is an extra aesthetic dimension that gives the animal doer control and provides innate sensory and cognitive feedback.

The knowledge gained from prototyping and testing informed our interaction design work such that we were able to establish key principles relating to interface design for elephants – **consistency, differentiation, graduation, specificity, multiplicity** and **affordance.** Through the Concept Craft Cards, we have highlighted our insights and suggested some important topics for ACI researchers to consider when working on UX design and development for non-human animals.

Future Research

Designing enrichment technology for an elephant required a leap of imagination. Importantly, the interface design and the concept design were interrelated problems, with the evaluation of one feeding back into the design and development of the other. This symbiotic relationship between concept and implementation meant that our design interventions constantly evolved during the project.

There are challenges associated with the making (and deployment) of an interactive device for an elephant that are distinct from the original challenge of designing the artefact. Some are associated with an elephant's distinctive characteristics - building a robust system for an animal so completely alien in physique, sensory apparatus, mode of behaviour and typical habitat requires great attention to detail. Other challenges are technical and arise while prototyping systems with embedded technology – for example, some kinds of sensors turn out to be more suitable for a human habitation than an elephant enclosure. There are other issues that can be categorised as political in that they depend on the attitudes and preconceptions of the various human stakeholders - some zoos already have clear protocols with regard to the manufacture and introduction of novel devices and these make no allowance for trial and error. In other words, the process of iteratively prototyping and refining designs with the animal becomes impossible in some situations. Various challenges arise at different points during the project timeline, but typically start with the need to handle the ethics protocols.

The exploration of these challenges is the story of this research. On a practical level, working with elephants has been both fascinating and frustrating, while in terms of research and dissemination, the elephant's iconic status triggers immediate interest, which has often been useful. In the world of human toys and games, the designer is forever pursuing novelty and engagement, perhaps with educational value or cooperative play thrown in the mix to lend the practice an alternative motive. Similarly, the quest to design an interesting experience for a captive animal is never-ending, and these early forays with elephants are just the start of an exciting journey.

Our research has raised as many questions as it has answered, and this final chapter highlights these questions, as well as considering the future direction of our work with elephants.

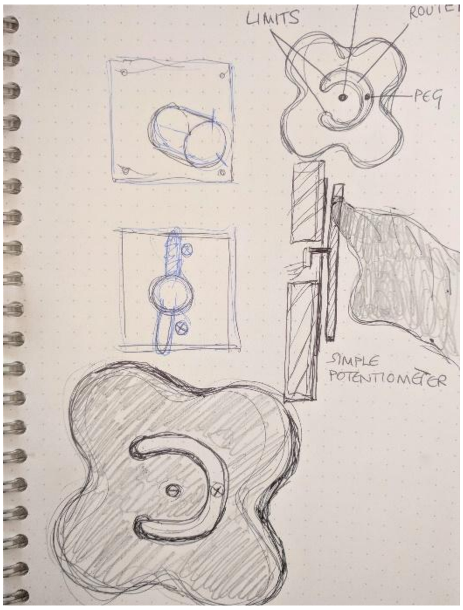
In *Chapter 3: Methodology*, we discussed elephant requirements, and called attention to two distinct but inter-related topics, which we recap here: (i) **Interface** – How might an elephant interact with a technology-enabled system? What are interface design requirements? (ii) **Experience** – How can we imagine what might be inherently interesting and useful for a captive elephant? What might such a system offer an elephant by way of an appropriate experience?

In regard to **interface design**, we were able to design and craft systems that elephants could reliably use, devising a range of usable interfaces. The early prototypes were essentially different kinds of buttons. There are many different ways to implement buttons and switches, and some may be easier for a non-human animal to understand than others. We raised questions that merit further investigation, relating to *system status* and *placement of controls*:

> *Does the button remain 'ON' after triggering, or does it revert to 'OFF' as soon as the interaction stops? If it remains ON, how does the animal change the status? Using the same button? How does the animal know whether the button is currently ON or OFF? Does the button itself offer some indication of its status (like a switch)? Would this require the interaction design of the device to offer feedback that was distinct from the output that it triggered? If we supplied a series of vertical controls, would the elephant perceive a hierarchy? Does a higher position for a button indicate greater importance because older (and taller) animals are probably higher in the hierarchy of the herd? On the other hand, if buttons were laid out horizontally, might that be confusing? Would an elephant recall which button performed which task? What is the maximum number of buttons that could be used by an elephant?*

In *Chapter 5: Design and Craft*, we elaborated on our interface question by asking: What qualities would make an interface easily usable for an elephant? While researching the most suitable attributes for the controls, we began to explore the aesthetic qualities of the interfaces, considering the overall experience for the user; we focused on the pleasure associated with the encounter from an elephant's perspective. In this endeavour, we believe we were successful; however, the difficulties we experienced mapping inputs (e.g. elephant interactions) to outputs (e.g. water or sound effects) meant that it was hard to assess what kind of *meaning* an elephant user associated with a device interface. This is an area that we suggest could be investigated further. Our own work would probably take this forward in the context of acoustic preferences, while others may find it interesting to take this forward in the context of alternative meanings.

Our investigation of acoustic enrichment led us to the design of a device with 'instrument-like' qualities, whereby an elephant could potentially control the quality of the audio being played. This was an attempt to address the question of **elephant experience**, which we approached by asking these questions: (i) What experience do I want an elephant to have? (ii) What is essential to that experience? (iii) How could a playful interactive system capture that essence? (from *Chapter 3: Methodology.*)



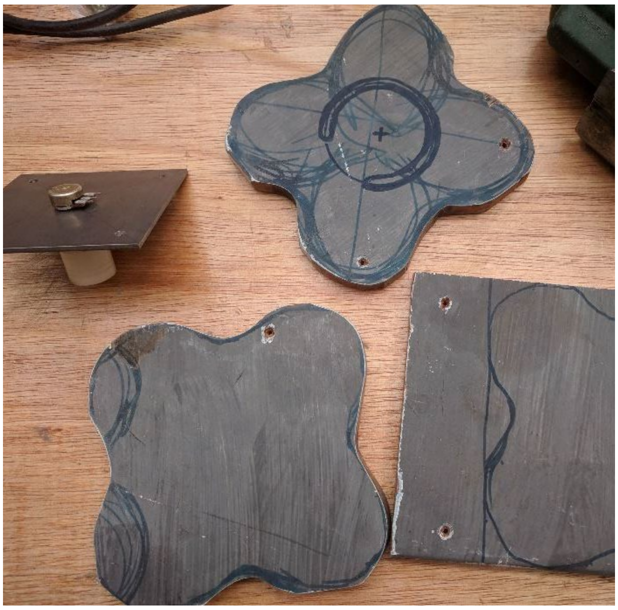


Figure 44: Elephant knob - sketches and prototype using potentiometer or rotary encoder

The purpose and nature of the interactive device we were designing was an important question for us and turned out to be surprisingly challenging. We established enrichment goals that we believed to be achievable – cognitive and sensory stimulation – and declared an early interest in playful systems. However, we recognized that elephant play is normally an *improvised* activity, categorized as 'paedia' rather than 'ludus'. Spontaneity is typical of this kind of play. Although we believe that elephants are capable of understanding and following simple rules devised by humans in order to play a structured game, we wanted to avoid the enrichment experience becoming a training exercise that required food rewards. Rather, we hoped to discover what other intrinsic rewards would delight an elephant to the extent that she would be motivated to engage with our system for repeated experiences. Musical instruments are not categorized as toys, yet the verb 'play' is used to describe how humans use them, across many European languages (French – jouer, German – spielen, Italian – giochiate, Spanish – tocar). Similarly, improvisation is a concept strongly associated with both musical performance and playing. Perhaps therefore, an interactive noise-making object might hold some interest for elephants, who improvise when they play, if they are able to control the acoustic output at will.

Other questions we identified in *Chapter 3: Methodology* in relation to acoustic enrichment include: What kinds of sounds? How would an elephant be able to play with them? What kinds of controls could she understand? How would it be possible to construct such a device?

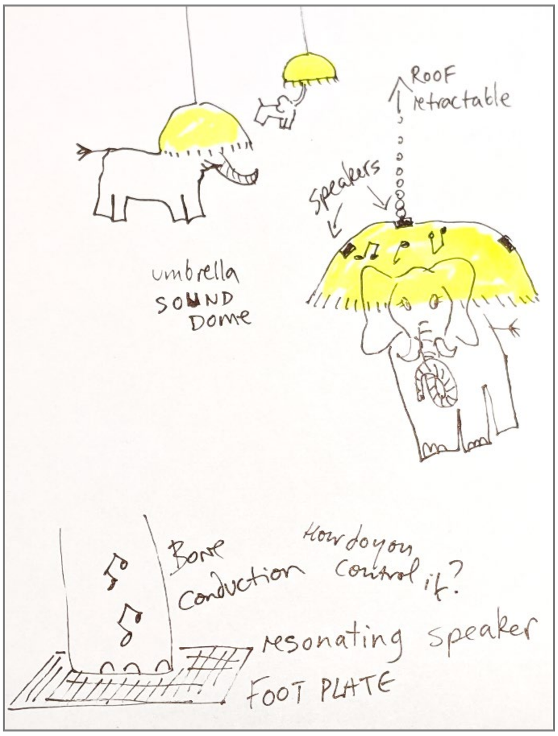


Figure 45: Personalised audio for elephants - concept sketches

This research is on-going. We hope to develop it further, by offering a variety of controls that enable an elephant to manipulate an acoustic signal. We were able to craft a giant *slider* that offered a graduated control, allowing analogue input from the user; we are currently experimenting with the design of a knob (see Figure 44: Elephant knob) which would also provide analogue input. This system has yet to be presented to any elephants; unfortunately, current restrictions mean that we are unlikely to have access to Valli and Lakshmi or introduce them to new devices for the foreseeable future. Therefore, our immediate research is likely to be more conceptual and less crafted (at elephant-scale).

Working with acoustics has challenges – as we have pointed out, audio is pervasive, yet we would hope to offer each animal a personalised experience. This has raised other questions for future research, relating to elephant *social dynamics* (from *Chapter 6: Reflections on Design and Craft*). We identified these questions in Chapter 6: Would it have made a difference to the elephant testers if the features were spaced further apart? How big is an elephant's personal space with regard to enrichment experiences? Would elephants take turns playing with a system? How likely would they be to share?

Taking these queries forward into a design space, we ask: How would it be possible to offer each elephant a unique experience without impacting on others in the vicinity? Could we design an 'elephant listening pod'? Or investigate the potential for 'radio foot-plates' that provide acoustic experiences via bone conduction? (See Figure 45: Personalised Audio.)

There are many reasons why it might be interesting to explore audition in animals. Research involving enrichment devices may not just be for its own sake – in other words, to determine whether the animal's well-being is improved through engagement with the device – but could also potentially contribute to our knowledge of the species, and indeed to our understanding of audition in general. By monitoring an animal's use of acoustic enrichment, we may be able to learn about their cognitive abilities and preference for different kinds of sound, which could enable us to design acoustic interactions for animals that are biologically salient and species appropriate, and which in turn could support research into animals' perception and communication, including with our species. Indeed, we have the cognitive ability and technology to be able to capture and analyse the vocalisations made by other species. It may be that our systems could inform other kinds of systems yet to be developed that help elephants in the wild and thereby protect their future. For example, a wild elephant might be able and willing to trigger a strategically positioned interactive 'alarm' device if she perceived the presence of human poachers – thereby alerting the appropriate authorities and summoning help.

Finally, we hope that our research with elephants will lead to a deeper understanding of interaction design for other non-human animals. Devices built for elephants could be repurposed for other species; the interface designs are reusable in different contexts. Through our Concept Craft Cards, we aim to share some of the knowledge we have acquired along the way, and we plan to test and refine these over the coming years with the support of colleagues in the ACI community.

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Appendices

A1: Ethics Forms

This section includes the following ethics forms, required before undertaking any research work with elephants.

- Woburn Safari Park
  Submitted to Head of Learning (Adele Clegg) at Woburn in July 2013, requesting permission to undertake observations and later to introduce some enrichment toys to the elephant environment. There was no response to this request, despite repeated emails and calls from research team.

- Colchester Zoo
  Submitted to the Education and Research Dept at Colchester Zoo in December 2013, requesting permission to undertake observations. This request was granted and the study commenced in January 2014, over 3 months. The period was extended and I discussed informally whether I could deploy some enrichment with the elephants. This request was rejected in May 2014, on the grounds that it would take up too much keeper time.

- Blair Drummond Safari Park
  Submitted to Blair Drummond after an informal meeting in February 2014, requesting permission to test prototype devices with the elephants. Our elephant contact at Blair Drummond subsequently left the park, and by this time we had made contact with the keepers at Skanda Vale in Wales (which was easier for travel), so this application was dropped.

- Open University AWERB + feedback and approval
  We submitted an ethics approval form to OU ethics committee in March 2015, around the time we started testing prototype devices with Valli at Skanda Vale. After addressing questions from the committee, the request was approved.

Woburn Safari Park Research proposal application form

Send completed application to:	Adele Clegg Head of Learning Woburn Safari Park Woburn Bedfordshire MK17 9QN

Date 18th	July 2013
Principal Investigator	Fiona French
Position	Senior Lecturer at London Metropolitan University; PhD student at Open University
Contact Phone Number	44 7989142822
Email	f.french@londonmet.ac.uk
Institution/ Affiliation	Open University
Institution Address	Milton Keynes
Supervisor (if applicable)	Clara Mancini; Neil Smith; Helen Sharp
Supervisor Phone Number	
Supervisor Email	**clara.mancini@open.ac.uk** **neil.smith@open.ac.uk** **helen.sharp@open.ac.uk**

Title of Project **Developing Digital Toys and Games to Facilitate Inter-Species Communication**

Please tick all study requirements	1. Behaviour observation	Y	☐
	2. Animal contact		☐
	3. Diet manipulation		☐
	4. Visitor survey/observation	Y	☐
	5. Botanical project		☐
	6. Utilises exhibit animals	Y	☐
	7. Utilises free ranging animals	Y	☐
	8. Utilises off-exhibit animals	Y	☐
	9. Requires non-invasive sampling		☐
	10. Requires post mortem materials		☐
	11. Other, please describe	Y	☐
	Novel items may be introduced to animal enclosures.		

Species studied Elephants

Research summary. Attach a scientific summary of the aims and objectives of this project and of the methods, materials and animals to be employed in this project. Provide sufficient detail so that a careful evaluation of the project and its methodology can be made. Include full descriptions of the project's objective, methods, and expected results.

Developing Digital Toys and Games to Facilitate Inter-Species Communication

This project aims to facilitate playful interactions between humans and elephants by developing species-specific interfaces for toys and games such that elephants and human visitors can share game experiences together.

Objectives of this work include strengthening the bonds between humans and elephants by providing shared, non-threatening experiences and enriching the environment of captive animals by providing entertainment that stimulates their cognitive abilities as well as their natural behaviour patterns.

The first phase of the research entails understanding requirements for designing and developing interfaces that enable elephants and humans to interact with each other through a playful system. Requirements need to be elicited from all stake-holders – in this case, the elephants, their keepers, the park management and the visitors. I plan to observe the elephants and talk to their keepers, as well as to park managers and visitors.

The next phase of research will involve introducing some new elements into the elephants' living spaces and observing/monitoring their reactions. These elements might take the form of physical objects (toys) or systems that measure the elephants' sounds or movements.

At a later stage, I would like to introduce some digital toys into the visitor space and observe/monitor the reactions of the visitors to these novel objects. Ultimately, the goal of the project is to design, develop and deploy a system that incorporates two different interfaces - one with which elephants can interact and one that is designed for visitors. This system should be simple and intuitive and provide sensory feedback for the two sets of users which might be aural, visual or haptic; for example, the users might be able to exercise some control over a remote object.
Animal husbandry. Please specify any deviation from standard husbandry which your protocol may require, e.g. diet change, housing change, use of keeper time, change in animal group composition, etc.
In order to elicit requirements from the stake-holders, I would like to carry out various activities, none of which will require changes to the elephants' routine. Firstly, when compatible with Woburn Park work practices, I would like to spend some time talking to the elephant keepers, in order to obtain their perspective on what forms of interaction might be appropriate for elephants. I would also like to "shadow" the keepers during the day, observing the elephants' typical daily routine. Where possible and with the permission of managers and keepers, I would like to video the animals' interactions with each other, with daily objects, with their keepers and possibly with visitors, and make notes. In all such situations, I would act under the supervision of the keepers to ensure that the welfare of the elephants is not compromised. I would like to be able to observe the behaviour of all the elephants at different times of day, in different parts of their enclosure and in different weather conditions, which will entail a number of visits to the park. Where appropriate, I would like to talk to visitors about their interaction with the elephants, perhaps by handing them short questionnaires and inviting them to submit some information online. At a later stage, I would like to introduce new elements (toys) into the elephants' living environment and make further observations. I will submit a specific ethics form nearer the time in order to request approval for this stage of the project.

Woburn Safari Park Research Protocol

1. Policy

1.1. Research must be compatible with the mission statement and vision of the Park.

1.2. Research is encouraged if it links into or is relevant to the Park's animal collection, conservation programmes or education programmes.

1.3. Research must be for the benefit of individuals, the species being studied or the organisation. If this cannot be demonstrated, clear learning outcomes must be apparent.

1.4. All research must be assessed and approved to ensure scientific and ethnic validity, to ensure that animal welfare is not compromised and that it complies with all UK and EU legal requirements.

2. Application process

2.1. Applications for short term research placements (under 30 days) must be submitted at least 60 days prior to the commencement of research.

2.2. Applications for research placements (over 30 days) must be submitted at least 90 days prior to the commencement of data collection.

2.3. Students wishing to combine research with a work placement for a period of 8 months or longer may be allowed to start without an approved project, given that a research application is submitted and approved within 4 months of the start of the placement. Failure to do this could lead to termination of the placement. Long term placement students (8 months or longer) should attend an induction and be given the training necessary to carry out research and work in the relevant section.

2.4. All research will be assessed by the research coordinator, Head of animal collections in conjunction with senior staff within the area of study. Reviewed projects will need further authorisation by the Duke of Bedford prior to research commencing.

2.5. Short term placement students will be informed if their research is approved or rejected no later than 30 days from the date the application form has been submitted. Once reviewed, long term placement students will be invited for an interview with the Duke of Bedford no later than 42 days prior to research commencing and student informed no later than 30 days from date of requested commencement as to decision outcome.

3. Terms and Conditions

3.1. Researchers must read and comply with all health and safety guidelines and instructions from keepers.

3.2. Woburn Safari Park may provide background information on the Park and specific animals as well as facilitating logistics of study. Woburn Safari Park cannot be relied upon to provide any academic supervision or tuition.

3.3. Any amendments to the project after it has been approved must be authorised by the Duke of Bedford before they are put into practice.

3.4. Research can only be carried out during normal working hours. Out of hours research is not permitted unless specifically arranged, permission is sought and there is adequate staff cover.

3.5. A copy of the research material (data and draft) must be submitted to Woburn Safari Park staff for authorisation at least three weeks prior to the research being published or submitted for 3rd party review. Material for submission will reviewed for accuracy of information relating to Woburn Safari Park and confidential information. Woburn Safari Park reserve the right to request that any material deemed unreasonable shall be removed from the document.

3.6. All research must be reported in full and reports should acknowledge Woburn Safari Park. Individuals contributing to research should be acknowledged through co-authorship or by name in the relevant section of the project, as agreed between researcher and staff prior to research submission.

3.7. Two copy of the final project/report should be submitted and retained by Woburn Safari Park. A £100 deposit must be paid in advance of commencing research. This will be refunded on the receipt of the final submitted documents.

3.8. Researchers must sign a confidentiality agreement prior to the start of the research (please find below).

3.9. Researchers must behave in an acceptable way at all times. Failure to do this could lead to termination of project.

3.10. Accommodation is not provided or arranged for students. Finding it is the student's own responsibility. Transportation to and from Woburn Safari Park is also the responsibility of the researcher. We can offer no financial contributions for living expenses or payment for work undertaken to researchers.

3.11. Researchers must be affiliated with a recognised academic institution and, if deemed necessary, references maybe taken up.

3.12. Research Students must sign a confidentiality agreement prior to commencement of research.

4. Ethical Policy for Animal Research

Woburn Safari Park operates within the laws of UK and EU and abides by the ethical policies set out by BIAZA and EAZA.

4.1. Woburn Safari Park does:
- Try to use its animal collection to contribute to the advancement of biological knowledge.

- Undertake and encourage non-invasive scientific research which aims to enhance animal welfare, husbandry and conservation.
- Review all research proposals to ensure they will not cause pain, suffering, distress or harm to the animals. Woburn Safari Park also strives to ensure that proposals are of an acceptable scientific standard and that they will not disrupt the normal workings of the Park.
- Aim to increase staff and visitor knowledge through promoting research.

4.2. Woburn Safari Park does not:

- Hold a Home Office licence or allow any research requiring a Home Office Licence. (The Home Office Animals (Scientific Procedures) Act 1986).
- Restrain or forcibly separate animals from their group solely for the purpose of research.
- Introduce any item or change in husbandry procedure which could cause a reduction in welfare or an adverse reaction, e.g. increased aggression in the group, solely for the purposes of research.
- Allow any kind of research which could prove detrimental in any way to health and well being of the animal.
- Allow research that negatively impacts upon Woburn's visitor experience.
- Allow research to impact the smooth operation of the Animal Department unless, in exceptional circumstances a significant benefit can be demonstrated.

5. Health and Safety for Researchers

Working amongst animals put researchers in potentially risky situations that differ from other areas of work. In order to minimise these risks it is critical that students understand the risks present and follow the instructions of Woburn Safari Park staff at all times. Below is briefly summarised those areas of risk researchers are most likely to encounter at Woburn Safari Park. It is critical that researchers are confident in handling and avoiding all the risks they are likely to encounter in their study. Researchers should not undertake any task for which they are not adequately trained to carry out safely. If researchers have any doubts regarding anything they are planning to do, the issue must be raised with senior staff within the area of study and satisfy all those involved that risks have been adequately minimised before proceeding.

This document will only focus on those areas of risk that are peculiar to general research within the animal department at Woburn Safari Park. This document will not cover those areas of risk that are likely to be encountered in other areas of life such as preparation of hot drinks, walking on uneven surfaces, manual handling, food preparation etc. It is expected that staff should be capable of dealing with such every day risks through the application of common sense. However, those researchers that do have concerns in particular areas of their study, must consult senior members of staff to discuss such concerns, and where appropriate receive guidance.

Below is listed the key risk areas together with very generalised advice. Researchers will receive more specific instruction from animal department staff upon arrival.

5.2. Zoonoses

Definition: The risk of infection/infestation from animals within the collection.
Areas of risk: All animal areas.
Avoidance: Limit all unnecessary contact with animals, surfaces to which animals have had contact, faeces, urine, blood and secretions from animals. Ensure all cuts are appropriately bandaged to prevent infection. After contact with animals or derivatives from animals, ensure appropriate hygiene precautions are taken, namely washing with appropriate soap under running water. Researchers must be particularly diligent prior to eating and when have open wounds. When cleaning houses using pressure washers, or any method that may generate an aerosol, it is important to wear appropriate protective masks.

5.3. Physical trauma caused by animals

Definition: Any injury caused by an animal, this may include biting, kicking, scratching, crushing etc.
Areas of risk: All animal areas.
Avoidance: Limit all unnecessary contact with animals. Researchers are not to enter animal areas unless supervised by a member of Woburn Safari Park staff. Awareness is essential around any animals.

5.4. Trauma caused by machinery/vehicles

Definition: Any injury caused by a mechanical equipment, crushing etc.
Areas of risk: All animal areas.
Avoidance: Limit all unnecessary contact with machinery. Researchers are not to enter areas in which machines are operating unless supervised by a member of Woburn Safari Park staff. Awareness is essential where machines and vehicles are operating.

Supervisor Statement:

I (Student supervisor) confirm that I have given permission for (Student name) to undertake research work at Woburn Safari Park.

Signature:

Date: / /

Researcher Statement:

I (Student name) confirm that I have read the Woburn Health and Safety for Researchers document. Moreover I confirm that I am comfortable in dealing with all the risks that may be presented to me as a researcher at Woburn Safari Park. Furthermore I agree that I will not endanger my own health or those animals and staff around me by placing myself in a potentially risky situation for which I have not been adequately briefed or have not been adequately provided for in terms of equipment. I agree that I will follow the instructions of Woburn Safari Park animal staff at all times and if ever in doubt of potential risks, will consult said staff.

I also confirm that I have read the research policy document and I understand that failure in abiding the terms and conditions stated in this document may lead to the termination of the research placement. Moreover I agree that the information I learned and gathered during my placement at Woburn Safari Park may be confidential and should not be communicate verbally or in writing, unless relevant to my research, without approval of senior staff.

Signature:

Date: / /

Research Application Form

Please complete this form if you wish to undertake research onsite at Colchester Zoo. The information you supply on this form will enable us to assess whether we can accommodate your research. In order to assess your application as fully as possible, please also provide a full research proposal if available.

Please return the form by post, email or fax to: Education and Research department, Colchester Zoo, Maldon Road, Stanway, Essex CO3 0SL, amanda@colchester-zoo.co.uk or research@colchester-zoo.co.uk Fax 01206 331392

Personal details

Title: MS **First name: Fiona** **Surname: French**	
Term address: **Tel:** **E-mail:**	**Home (long-term, e.g. family) address:** **82 Rowditch Lane** **London** **SW11 5BX** **Tel: +44 (0) 7989142822** **E-mail: f.french@londonmet.ac.uk**

Which is the easiest method to contact you about this request: Email / phone

Academic details

Course, including level (HND/BSc/MSc/PhD): PhD Animal Computer Interaction
Academic institution: Open University
Academic supervisor: Clara Mancini **Tel: +44(0)1908652165** **E-mail: c.mancini@open.ac.uk**

Project details

Project title: Developing species-specific playful interfaces for cognitive enrichment
Is this project from the list of priority topics produced by Colchester Zoo? Yes / No
Project aims:

- To develop species-specific interfaces for toys and games, in order to enrich the environments of captive and domesticated animals by alleviating boredom and stimulating natural behaviour patterns.
- To enable humans to appreciate the complexities of animal behaviour and communication using technology as part of a development toolkit.

Project rationale (e.g. why is this research important? What is the value of this research to captive breeding programmes / conservation)? Please continue on additional sheets if necessary:

This research considers the design of technology-enabled products that can be used to explore modes of interaction and communication, specifically in the context of playing. Computer-mediated interactions usually fall within the scope of Human Computer Interaction, but this project aims to broaden participation by including animals within the framework.

The freedom to express normal behaviour is one of the Five Freedoms (UK Farm Animal Welfare Council 1992), used as measures to judge animal welfare. In captivity, different forms of environmental enrichment can be very effective in promoting natural behaviours. For example, to promote foraging, a common practice is to scatter or hide the food supply so that foragers have to search for it, instead of supplying food in a bowl. However, searching the floor of the zoo enclosure is still lower quality behaviour for captive animals than that exhibited by their wild counterparts, who might be simultaneously watching out for predators, using tools to crack open nuts etc.

In general, captive animals are not required to use their brains to full capacity, which can lead to a range of psychological and physiological problems, such as boredom and associated stress. The opportunity to play can be an environmental/cognitive enrichment activity that promotes the expression of some natural behaviour patterns which might otherwise not be expressed in a captive environment. (Young, 2003, p.29)

Young animals play for many reasons, seemingly including: [i] practising skills they will use as they grow, such as hunting and fighting behaviours, [ii] reinforcing social bonds, [iii] establishing hierarchies by understanding their own physical limits and those of others, [iv] exercising. (Goodenough, 2009, p.158) It is commonly believed that playing is also an important part of normal development in animals. Adult animals, on the other hand, rarely exhibit playful behaviour, probably because in the wild, they have to spend their time foraging or hunting to survive (consistent with Maslow's Hierarchy of Needs, 1943). Recent research has shown that they play more when their dietary requirements have been met – typically in captivity. (Goodenough, 2009, p.159)

I believe that toys and games have the potential to engage animals of all ages in pleasurable activities that stimulate their brains, sharpen their senses and test their muscles. Introducing the right kind of playful equipment into a captive situation can provide animals with fresh challenges and help them to develop new skills. Successful manufactured solutions have included puzzle feeders, toys, musical devices, swings etc.

Robert Young (2003) emphasises that environmental enrichment provides benefits to both animals and their care-givers, empowering both parties. There is an educational benefit to the public if zoo animals are behaving naturally, and it is possible to imagine a huge positive impact on visitors if they are able to interpret animals' behaviour and remotely "share" experiences with them (perhaps by trying the human interface to a similar game).

One of the advantages of using technology to facilitate a playing experience is that it can enable the collection of a rich set of data from the participants, which can then be used as metrics for further analysis. It might subsequently be possible to build a model of a player (human or other) and thereby gain deeper understanding of how that player behaves, similar to the way in which current computer games manifest believable agents using (simple) artificial intelligence.

My field of interest and expertise is in the general area of physical computing, computer games and toys and I would like to expand my research into the space that exists where we interact with other creatures, using technology to mediate that experience. Current research in this area includes the use of interactive touch-screen devices for pigs and primates and the use of Kinect sensors to capture movement in primates.

My primary objective is to investigate how to design a system with an interface that works for elephants. I would like to find out whether introducing the right kind of playful equipment into a captive situation could provide animals with fresh challenges and help them to develop their skills, promoting the expression of some natural behaviour patterns. Elephants are known to be playful and social, so they seem good candidates for such a project.

Methods

Type of study (please highlight):

Observational (no modifications) – YES

Experimental (modification necessary)
Sample request (e.g. faecal)- PLEASE FILL IN THE 'INFORMATION REQUEST' FORM

Methodology, including pilot study, manipulations, sampling, data collection, statistics:

A user-centred design approach initially requires a complete understanding of the context, which would involve an ethnographic study of the elephants.

Jesse Schell (2008) states: "The most important skill for a game designer is listening." How do we listen to animals? According to Muller (2003), "Participatory design ... was founded on the principle of political inclusion, (but) needs new ideas in order to be universally inclusive." We need to broaden the scope of Schell's claim to include the use of other senses that might help us to make sense of another species' responses. It may be that technology can help at this stage, by capturing data that humans cannot perceive.

McFarland (2008) comments: "Different species in different environments exhibit a wide variety of types of intelligence." He points out that such intelligence is difficult to define and that we should strive to study it from a design point of view as well as looking at the mechanisms involved. This means considering how the species achieves autonomy, meets goals, exhibits behavioural flexibility and communicates its intentions.

Stages
- Meet elephant keepers and discuss ideas with them.
- Observe elephants at different times of day, in different weather conditions, in different contexts
- Collect data remotely – such as video, estimation of time budget etc.

Further research opportunities:
Relate to interface design, deployment and evaluation, not within scope of this application.

Support required from Colchester Zoo, including facilities, equipment:

- Opportunity to meet elephant keepers and spend short periods of time talking to them.
- Opportunity to visit elephants inside and outside, make detailed observations of enclosures and animal behaviours
- Discuss realistic possibilities for future development (ie. How to introduce novel interfaces)

Relevant reference material, e.g. books, journal articles:

1) Goodenough J, McGuire B, Jakob L (2009) Perspectives on Animal Behaviour, John Wiley & Sons.

2) McFarland, David (2008) Guilty Robots, Happy Dogs: The Question of Alien Minds, OUP

3) Muller (2003) Participatory Design: The Third Space in HCI; The Human-Computer Interaction Handbook; L. Erlbaum Associates Inc.

4) Schell, Jesse (2008) The Art of Game Design, Morgan Kaufman

5) Young, Robert (2003) Environmental Enrichment for Captive Animals, Blackwell Science Ltd

Will you be using any specialist equipment which may require certain operating conditions?

No

Data collection period

Proposed data collection period (DD/MM/YY – DD/MM/YY):

I would like to start as early as possible – in Jan 2014

Estimated number of days per week:

1-2

Estimate number of total days:

10-12 initially.

Is there any other additional information which may help us in our decision (e.g. support from a recognised scientific body or organisation, involvement with other zoos):

I have had a long discussion with the EWG, headed by Lisa Yon, as recommended by Rebecca Perry. The advice and information I received from members of the group has been invaluable in helping me shape some of my design ideas. My next step will be to try and involve the Association of Elephant Keepers in some informal discussions about possible interface designs.

What is the latest possible deadline that you require a decision on this application?

Before Xmas if possible

Would you be willing to supply Colchester Zoo with a copy of the final report produced using this information: Yes

Please continue on another sheet if necessary

PLEASE ATTACH ANY OTHER ADDITIONAL INFORMATION
E.G. RESEARCH PROPOSAL/ LETTERS OF SUPPORT FROM ORGANISATIONS OR TUTORS

Applicant's signature: ____

Date: __________

Supervisors' signature: ____

Date: ____________
I understand that by signing above I have agreed to supervise the project outlined in the proposal.

Office Use Only

Date application received:
Copied to relevant staff:
Decision made: **Accepted/Rejected**
Applicant informed of decision:
Additional comments:

Blair Drummond Safari and Adventure Park
Research Project Application Form

Please complete the following in black ink using block capitals. All information on the below forms is strictly confidential and will not be disclosed to any third parties without your consent. All applicants must be over 18.

1) General Information

Title:	Mrs/ Mr/ Miss/ Ms/ Dr
First Names:	Fiona
Surname:	French
Date of Birth:	01/05/1963
Address:	82 Rowditch Lane, London SW11 5BX
Home Phone Number:	
Mobile Phone Number:	07989142822
Email Address:	f.french@londonmet.ac.uk
Name of Academic Institution:	The Open University
Address of Academic Institution:	Walton Hall Milton Keynes MK7 6AA
Course Title:	PhD in Animal Computer Interaction
Year of Study:	2nd year, part-time

2) Project Information

Project Title:	Audio toys for elephant enrichment
Hypothesis/ Aims:	This research aims to explore the potential of introducing an acoustic toy to captive elephants, as well as testing an interface that elephants might be able to use in order to control an aspect of their environment.
Proposed Start Date of Project:	October/November 2014
Proposed End Date of Project:	May 2015
Animals You Wish to Use:	Elephants
Planned Output of Study, e.g. dissertation, peer-reviewed publication:	Report on findings + analysis of data collected, conference paper/peer-reviewed publication, physical artefact and potentially future applications
Name of Project Supervisor:	Clara Mancini
Contact Details of Project Supervisor **Phone Number:** **Email Address:**	 c.mancini@open.ac.uk

3) Additional Information

Allergies:	N/A
Medical Conditions, e.g. Diabetes, Epilepsy:	

Please note:

- If you do have allergies to any animals/furs/feathers then you may want to consider whether being in close proximity to animals is going to adversely affect your health.

- All researchers should have an up to date Tetanus vaccination. We also recommend that you should have an up to date Hepatitis B vaccination.

Name of Person to be Contacted in Emergency:	Dominic O'Riordan
Relationship to Yourself:	Partner
Address:	82 Rowditch Lane, London SW11 5BX
Telephone Number:	07989411191

4) Research Guidelines

1. Ethical guideline forms, from both the park and the researcher's academic institution, must be completed before the start date of the research project.

2. Before commencing the research project at the park, researchers must be aware of and comply with health and safety guidelines.

3. Researchers must read and accept the terms and conditions of Blair Drummond Safari Park's Research Policy.

4. Researchers will have access to the park's library, where all previous research projects plus other useful research materials will be available; however this material must not be removed from the library.

5. Researchers must be aware that some animals in the park may be moved or, in case of veterinary emergency, made unavailable for study. In this case the Research Department will keep researcher up to date and informed of the situation. Blair Drummond Safari Park will not be held responsible for any problems arising during research periods.

6. Researchers must not harm or distress any of the park's animals during their study.

7. Researchers must provide a copy of final research project and annotated data on completion of research period.

I have read and understood the above Research Guidelines and I agree to abide by them.

Signature.......................................

Date... 23/09/2014

Please send completed application forms to:
Research Department
Blair Drummond Safari and Adventure Park
By Stirling
FK9 4UR

ANIMAL WELFARE ETHICAL REVIEW BODY

RESPONSES TO AN APPLICATION FOR NON-LICENSED RESEARCH

The primary objective is to investigate how to design a playful system with an interface that works for captive elephants (and optionally other zoo and wildlife park animals) in order to provide them with cognitive stimulation; to develop, implement and test such a system.

Reply to feedback from the AWERB membership:

1. No evidence is included to suggest that elephants will be benefited from the provision of acoustic toys, so cannot assess the benefits against risks.

The goal of the design is to provide environmental enrichment (cognitive and sensory) for the elephants, by producing a system that offers them control over an aspect of their environment. Inspiration has been taken from the field of game and toy design, because playful behaviour is considered a hallmark of good welfare in captive animals (Young, 2003).

The research is exploring the design of such a system, both by developing a usable interface and by trying out various design concepts suggested by keepers and inspired by research into elephant behaviour in the wild and in captivity. We expect the design process to be iterative; based on the background work carried out so far and on discussions with various experts, potential concepts include acoustic toys and self-operated showers.

2. It is not clear why 7 elephants are needed (stated in part 8). Contradictive, it said only 3 elephants are to be involved in Part 14. Generally, there is no justification for the proposed number and type of animals used.

The first part of the research included observing 4 African elephants over a period of 3 months and speaking to their keepers at Colchester Zoo. Prior to starting this work, I submitted an application for ethics approval to Colchester, which approved it. I also completed an ethics approval form for AWERB, but I realised later that I had not submitted it at the same time.

Subsequently, I made contact with other institutions (Skanda Vale and Blair Drummond, both recommended by Mark Kingston Jones from The Shape of Enrichment - www.enrichment.org/). Skanda Vale keep 1 Asian female and Blair Drummond have 2 African females, bringing the total number of elephants to 7. In fact, the current application is requesting approval to test multimodal enrichment with only 3 elephants – at Skanda Vale and Blair Drummond. Please accept my apologies for any confusion.

3. The elephants will have direct contact of the interfaces. It is not clear whether the materials or the design of the interfaces will harm or distress the animals. Would be useful to have a risk assessment on cut, choke and electric shock hazards. Would a contactless system more appropriate?

The primary researcher has taken a 4 day certified course in environmental enrichment in August 2014, which covered a number of potential hazards. This was in order to ensure that any interactive designs for elephants explored within this project would be safe. A device with a contactless interface would certainly be feasible, but as we are interested in investigating the possibility for haptic feedback, we would not want to rule out this option. At Skanda Vale, we will be working with the keepers to develop suitable "buttons" and other controls, using materials that they recommend. Electronics will be embedded in the system and not accessible to the elephant – everything will be safety tested before deployment.

A key component of the work will be to offer the elephant a range of possible choices, as well as control of the situation. For example, a shower device might be activated by 3 different switches, each of which offers a different thermal experience. The elephant will need to be able to discriminate between the switches in order to make her choice. We will be researching how to design a set of controls that enable this, as well as investigating what kinds of positive feedback the system might offer (eg. kinaesthetic, acoustic). At Skanda Vale and Blair Drummond, for example, the keepers have suggested that switches should be attached on the other side of a wall so the elephants can access them through a 30cm aperture. This means that visual discrimination would not be appropriate and we will investigate which other modalities may be effective.

4. Environmental enrichment should be such as to give animals the opportunity to express natural behaviour - what evidence is there that these devices will fulfill this criterion? Another concern is that by observing only this very small number of captive animals, the information gained on their behaviour might be skewed, as there is a possibility that these captive animals already exhibit a restricted behavioural repertoire or have developed abnormal or stereotypic behaviours. I should like to see consideration of a wider range of animals before the devices are designed.

Playful interaction may allow control and cognitive enrichment, without necessarily replicating natural behavior. The opportunity to socialise in large groups may be one of the behavioural traits missing from the repertoire of most captive elephants, but it is not viable to introduce without stressing the elephants.

I have completed an extensive literature review of elephant behavior and spent a short period (3 month) observing captive elephants. This has lead to a comparison of behaviours between wild and captive groups, with a view to identifying experience gaps. Some natural behaviours for wild elephants include antiphonal calling, making decisions (being in control of what they do in their environment), investigating their surroundings and playing with objects. Providing cognitive and sensory enrichment by offering a toy that provides acoustic stimulation which the elephant can control could meet some of these criteria.

These ideas have evolved over a 2 year period and in consultation with members of the EWG (Elephant Welfare Group – Lisa Yon, Phyllis Lee, Ros Clubb, Oliver Burman, Samantha Bremner-Harrison), keepers from a range of institutions (Claire Bennett, Head Elephant Keeper at Colchester Zoo; Chris Lucas, Head of Large Mammals and Ally Gillies, Chief Research Officer at Blair Drummond Safari Park; Brother Stefan and Brother Peter, keepers of Valli at Skanda Vale Ashram, keepers at Howletts Wild Animal Park), animal behavior experts Mark Kingston Jones and Chris Hales from The Shape of Enrichment, as well as Hannah Buchanan-Smith from University of Stirling and my supervisory team at the OU.

The small group size is a consequence of the available participants. One of the research outputs would be a method for user-centred design with animal participants, and it is our explicit aim for this method and related techniques to be applicable to many other situations, even if the precise artefacts used for these elephants are not necessarily generalizable to others. The development of animal-centred methodologies is a key aim of Animal-Computer Interaction research, towards which this project directly contributes.

5. The first step would seem to be to conduct a full review of all the literature relating to elephant behaviour, in addition to the proposed information gathering exercise, time spent time observing a number of elephants in a natural environment: only then will it be possible to discern the full range of natural behaviour patterns exhibited by elephants and design something that might be useful. This observation does not necessarily have to be carried out in situ but television programmes or similar could be used.

As mentioned, a literature review has been completed (please see attached) and information has been gathered from various experts, as well as via observation of some captive elephants. On-going studies of elephants, video footage and documentaries are of great interest in this project and I would be grateful if the AWERB could advice on relevant sources.

6. My worry is that the elephants might be startled by the devices.

Any devices would only be introduced into the enclosures as and when the keepers believed it to be appropriate. The devices will only be available to the elephants while keepers are in attendance and closely supervising their use. The keepers will be able to disable or remove the devices immediately if they think these are having any negative effects on the elephants. In addition, acoustic feedback will firstly be tested with elephants to ensure that the range of sounds does not cause them any stress, before introducing a novel device.

7. What happens if the elephants hate the acoustic signal and don't engage?

The elephant would have control over the system and any sounds would only be produced if she chooses to activate it, and even then acoustic feedback would only ensue for a short time upon activation. Should she choose not to engage with the system, we would then try other designs. Keepers have told me that they would like to provide shower controls as a first step for their elephants, moving on to acoustic toys when the elephant understands that she can use an interface to control things. In this respect, an auditory signal might be useful for discriminating between different controls, with the system providing correspondingly different rewards.

8. They indicate that they are going to talk to experts and keepers and I think they need to have these conversations first, before they submit a proposal for our review.

Although this was not mentioned in the proposal, we have had many conversations with experts. I understand that through the AWERB, I might have the opportunity to speak to more experts in the field of animal behavior, especially elephant experts, something which I would greatly appreciate.

9. The proforma says that "The primary objective is to investigate how to design a playful system with an interface that works for captive elephants (and optionally other zoo and wildlife park animals) in order to provide them with cognitive stimulation; to develop, implement and test such a system." There does seem to be an aspect here of generalising the conclusions beyond the small number of elephants involved (indeed possibly to other species – though in fact the 3 elephants mentioned are already from two different species which already have, as far as I know, fairly different behavioural characteristics) and we need a justification for using the number proposed – there's an argument that using just three probably non-typical animals doesn't allow the generalisation proposed. Also the proforma isn't even clear on what the number is – item 5 on the proforma mentions three, but item 8 says there will be seven of them. (Item 9 mentions also Colchester Zoo (and I see from their website that they have 4 African elephants which would make the number up to 7) – is that still intended, and if so, is there not some paperwork we should see?).

It has proved challenging to find zoos or wildlife parks that have elephants whose keepers are interested in participating in a project of this nature. When Mark Kingston Jones undertook his recent elephant survey for BIAZA (British and Irish Association of Zoos and Aquariums), he offered to ask everyone if they would be interested in working with us, which led to the contacts at Skanda Vale and Blair Drummond Safari Park. Mark has subsequently told me that 2 of my contacts on the EWG are embarking on their own research project into acoustic enrichment for elephants, which seems to suggest that the premise is not without some supporters. If our own project goes ahead, I have offered to share any findings with them.

If we manage to develop a device that allows one captive elephant to control an aspect of her environment, thereby offering her some enrichment, this may open doors in other establishments. We anticipate that different groups of elephants will need different kinds of enrichment and live with different environmental constraints, but it may be that the methodology and principles underpinning the initial design are sufficiently flexible that we can apply them to a new situation.

Elephants have different personalities so we do not expect that one game or toy will be popular with every elephant. None-the-less, our hypothesis is that it may be possible to design an interface that allows an elephant (any elephant) to use a set of controls. Good Interaction Design for humans is not only accessible but can also bridge cultures and nationalities - to achieve universal design principles, heuristics are applied to guide the design process. In this project we aim to explore the possibility of extending the design process to elephants, specifically in relation to the application area of Game Design as a potential approach to environmental enrichment.

10. There is maybe a specific issue that the Skanda Vale elephant is a different species (Indian elephant) from those at Blair Drummond (and at Colchester) which are African, and that it is kept in very different conditions (kept with no other conspecifics for 30 years), which I think would now be frowned upon in (e.g.) a zoo. One might argue that that creates all the more need for enrichment of its experience – on the other hand, I do wonder what in general terms might be learned from doing something on a single untypically-kept member of this species.

Generally, we would like to use technology to help provide a way for elephants to be able to exercise some choice and control, be cognitively stimulated and express some playful behaviour. We wouldn't expect to achieve one-size-fits-all solutions, but every success (and failure) would contribute towards our understanding of the problem and towards the development of better design approaches.

Enabling captive elephants to have more autonomy, by enabling them to express choices and preferences, could ultimately inform the design of systems that benefit wild elephants – a poacher alert, for example. Interactivity could also contribute to improve our understanding of play behaviour, which in turn could contribute towards stress management in a variety of contexts.

11. Also, item 29 on the proforma says that the ethical approval of Blair Drummond is required, and that it has already been obtained. But the Blair Drummond form that was attached seems to be the general application to do research there, which says (under point 4): " Ethical guideline forms, from both the park and the researcher's academic institution, must be completed before the start date of the research project." This seems to imply that there is a different form for local ethical approval there than the one we have been sent, despite the applicant saying on our proforma (item 29) that it is attached.

This is my error – I submitted the form I sent to Ally Gillies at Blair Drummond and the response has been by email, phone and during a recent visit when we discussed possible ideas in more detail.

A formal approval from Blair Drummond is still needed before any interventions are tested. Even at this stage, the concepts are fluid – keepers have expressed interest in my ideas but also have different agendas. Their enthusiasm for offering their elephants control extends to familiar environmental features and events - they had not previously considered offering a playful interactive device.

STRICTLY CONFIDENTIAL AND RESTRICTED

The Open University

ANIMAL WELFARE AND ETHICAL REVIEW BODY (AWERB)

PROFORMA FOR UNLICENCED RESEARCH INVOLVING ANIMALS

If you are planning to carry out research using animals which does not require a Home Office Licence, it is still necessary to obtain prior approval from the University's Animal Welfare and Ethical Review Body (AWERB). To gain approval, please complete the following proforma, using wherever possible non-specialist language that will be comprehensible to lay members of the AWERB, and submit it to the Secretary (research-ethics@open.ac.uk). The AWERB will consider your proposal as quickly as possible, and providing full information will help to expedite this process.

NB. If the proposal is a continuation of a project which has already been considered by the AWERB, and does not involve modifications to animal handling and treatment, or to the procurement of animals, it is not necessary to submit a new proforma.

Please complete all sections. If a section is not applicable, write N/A.

1 Name of Applicant	Fiona French		
	Department: Computing and Communications	**Faculty:** MCT	**Email address:** f.french@londonmet.ac.uk
2 Position in the University	PhD student		
3 Role in relation to this research (e.g. Principal Investigator)	Principle Investigator		
4 Brief statement of main Research Question	The primary objective is to investigate how to design a playful system with an interface that works for captive elephants (and optionally other zoo and wildlife park animals) in order to provide them with cognitive stimulation; to develop, implement and test such a system.		
5 Brief Description of Project (please specify if this is a new project)	This is a new project in collaboration with Skanda Vale Ashram, who keep one Indian female elephant, and Blair Drummond Safari Park, who keep two African female elephants. Initial research involved obtaining advice from the EWG (elephant welfare group) and a number of animal behavior specialists and care-takers. The research considers the design of technology-enabled devices that can be used to explore modes of interaction and communication, specifically in the context of playing and specifically to provide enrichment via cognitive stimulation and the production of natural behavior patterns in the captive elephant community. The primary researcher has completed an extensive literature review of elephant behaviour and spent a short period (3 month) observing captive elephants. This has lead to a comparison of behaviours		

between wild and captive groups, with a view to identifying experience gaps.

Some natural behaviours for wild elephants include antiphonal calling, making decisions (being in control of what they do in their environment), investigating their surroundings and playing with objects. Playful interaction may allow animals to exercise control and provide cognitive enrichment, without necessarily replicating natural behavior. Potential concepts include acoustic toys and self-operated showers.

The ideas have evolved over a 2 year period and in consultation with members of the EWG (Elephant Welfare Group – Lisa Yon, Phyllis Lee, Ros Clubb, Oliver Burman, Samantha Bremner-Harrison), keepers from a range of institutions (Claire Bennett, Head Elephant Keeper at Colchester Zoo; Chris Lucas, Head of Large Mammals and Ally Gillies, Chief Research Officer at Blair Drummond Safari Park; Brother Stefan and Brother Peter, keepers of Valli at Skanda Vale Ashram, keepers at Howletts Wild Animal Park), animal behaviour experts Mark Kingston Jones and Chris Hales from The Shape of Enrichment, as well as Hannah Buchanan-Smith from University of Stirling and my supervisory team at the OU.

Inspiration has been taken from the field of game and toy design because playful behaviour is considered a hallmark of good welfare in captive animals (Young, 2003). The research is exploring the design of such a playful a system, both by developing a usable interface and by trying out various design concepts suggested by keepers and inspired by research into elephant behaviour in the wild and in captivity. We expect the design process to be iterative; based on the background work carried out so far and on discussions with various experts.

The small group size (3) is a consequence of the available participants. If we manage to develop a device that allows one captive elephant to control an aspect of her environment, thereby offering her some enrichment, this may open doors in other establishments. We anticipate that different groups of elephants will need different kinds of enrichment and live with different environmental constraints, but it may be that the methodology and principles underpinning the initial design are sufficiently flexible that we can apply them to a new situation.

Elephants have different personalities so we do not expect that one game or toy will be popular with every elephant. None-the-less, our hypothesis is that it may be possible to design an interface that allows an elephant (any elephant) to use a set of controls. Every success (and failure) would contribute towards our understanding of the problem and towards the development of better design approaches. Enabling captive elephants to have more autonomy, by allowing them to express choices and preferences, could ultimately inform the design of systems that benefit wild elephants – a poacher alert, for example. Interactivity could also contribute to improve our understanding of play behaviour, which in turn could contribute towards stress management in a variety of contexts.

Good Interaction Design for humans is not only accessible but can also bridge cultures and nationalities. In this project we aim to explore the possibility of extending the design process to elephants, specifically in relation to the application area of Game Design as a potential approach to Environmental Enrichment. One of the research outputs would be a method for user-centred design with animal participants, and it is our explicit aim for this method and related techniques to be applicable to many other situations, even if the precise artefacts used for these elephants are not necessarily generalizable to others. The development of animal-centred

	methodologies is a key aim of Animal-Computer Interaction research, towards which this project directly contributes. The research will involve: (i) An ethnographic study of the elephants in their habitual enclosures, indoors and outdoors over an extended period; this will comprise observations of animals and interviews with their keepers and associated research officers. (ii) Discussions with animal behavior experts and other people who work with elephants (such as members of the Elephant Welfare Group). (iii) The design of appropriate systems using different controls and feedback mechanisms; for example, an acoustic toy with a button interface that allows the elephant to control production of sounds. (iv) Deployment and testing of the system with the elephants and their keepers; testing will involve collecting data on the usage of the devices by the animals. The research will always take place under the supervision of the keepers and will always fully comply with the ACI research ethics protocol.
	Approximate Start Date: January 2014 — Approximate End Date: January 2016
6 Name of Principal Investigator or Supervisor	Clara Mancini Email address: c.mancini@open.ac.uk — Telephone: 01908652165
7 Names of other researchers or student investigators involved	**1** **2** **3** **4**
8 Type of animal to be used, number and age range	Type: Elephant — Number: 3 — Age range: 30-40 years
9 Location(s) at which project is to be carried out	Skanda Vale Ashram (Wales), Blair Drummond Safari Park (Scotland); other facilities to be confirmed.
10 Statement of the ethical issues involved and how they are to be addressed (This will normally cover such issues as whether the risks/adverse effects associated with the project have been dealt with and whether the benefits of research outweigh the risks)	It may be possible that the elephants are disturbed by my presence, observing them and taking photographs, but this is unlikely as zoo and safari park animals are used to visitors; Valli at Skanda Vale is a Full Contact elephant who enjoys the company of several members of the community. The primary researcher has taken a 4 day certified course in environmental enrichment in August 2014, which covered a number of potential hazards. This was in order to ensure that any interactive designs for elephants explored within this project would be safe. A device with a contactless interface would be feasible, but as we are interested in investigating the possibility for haptic feedback, we would not want to rule out this option. At Skanda Vale, we will be working with the keepers to develop suitable “buttons” and other controls, using materials that they recommend. Electronics will be embedded in the system and not accessible to the elephant – everything will be safety tested before deployment. The interface that elephants use to control the device will need to be sufficiently robust, and discussions with keepers will take place before

	designs are finalised. It will be important to ensure that the animals can not destroy the buttons and that any electronics are completely inaccessible. The final designs will be dependent on the animals' enclosures, as different locations may have different places suitable for mounting new devices. Any devices would only be introduced into the enclosures as and when the keepers believed it to be appropriate. The devices will only be available to the elephants while keepers are in attendance and closely supervising their use. The keepers will be able to disable or remove the devices immediately if they think these are having any negative effects on the elephants. In addition, acoustic feedback will firstly be tested with elephants to ensure that the range of sounds does not cause them any stress, before introducing a novel device. We have taken advice from the EWG on what types of sounds could be stressful and have had discussions with keepers about elephants' personal preferences. A key component of the work will be to offer the elephant a range of possible choices, as well as control of the situation. For example, a shower device might be activated by 3 different switches, each of which offers a different thermal experience. The elephant will need to be able to discriminate between the switches in order to make her choice. We will be researching how to design a set of controls that enable this, as well as investigating what kinds of positive feedback the system might offer (eg. kinaesthetic, acoustic). In early discussions with keepers, there was a clear interest in provision of controls to the animals, so they could control environmental features in their enclosures. All the keepers recognized the benefit of giving choice and control to the animals in their care, without knowing how to design such a feature. The willingness of keepers at Skanda Vale and Blair Drummond to test some prototypes with the elephants suggests that the potential positive outcomes mitigate against any possible risks.
11 Is the project covered by The Animals (Scientific Procedures) Act 1986?	**Yes** ☐ **No** **X**
12 Please explain why it is or is not so covered.	No invasive or distressing procedure is envisaged by this project.
13 If the project involves animals in the wild, indicate why it is not covered by The Wildlife and Countryside Act 1980	N/A
14 What measures have been taken in this project to fulfil ethical commitments to the Reduction, Refinement and Replacement of Animals in Research?	**Reduction**: Only 3 elephants will be involved in the part of research that involves deploying a prototype, which is designed to enrich their environment meaning that they will be the direct beneficiaries of the research. **Refinement**: The aim is to produce a game or toy that elephants choose to engage with, so they will only ever engage with any of the systems offered if they choose to do so and if their care-takers and legal guardians have established that it is safe and appropriate for them to engage. The keepers will always be present and the use of the toy will be limited to a short time period every week. The toys will be comprehensively tested for safety and robustness before being proposed to the elephants. Researchers and keepers will act according to the best interests of the elephants at all times. **Replacement**: User-centred design necessitates the involvement of users in

	the design process for their own sake, so the research could not be carried out without the active participation of the elephants; however, in order to optimize their involvement, the proposed interfaces will be designed with the expert advice of elephant behavioural experts and the zoo keepers who know the animals. The elephants will only be involved at appropriate stages in the process.
15 Name(s) of Day-to-Day Carer(s) of the Animals involved	**Brother Stefan at Skanda Vale; Chris Lucas, Head of Large Animals at Blair Drummond Safari Park. The elephants are cared for at their respective facilities all the time and they will not be moved for the purpose of the research.**
	Emergency contact phone numbers of carers, inc. out of office hours:- N/A

Ownership of the Animals

16 Are the animals owned?	**Yes** X **No** ☐
17 If the answer to Q15 is "Yes", has informed consent been obtained from the owners?	**Yes** X **Please append documentary evidence to this form.** **No** ☐
	If "No", please state why not:

For All Work on Vertebrates or *Octopus Vulgaris*:

18 Does this research involve any procedure that may have the potential effect of causing the animal(s) pain, suffering, distress or lasting harm? ***[Note: Under the terms of The Animals (Scientific Procedures) Act 1986 "Pain, Suffering, distress and lasting harm", encompass any material disturbance to normal health (defined as the physical, mental and social well-being of the animal). They include disease, injury, and physiological or psychological discomfort, whether immediately (such as at the time of an injection), or in the longer term (such as the consequences of the application of a carcinogen). This regulation starts at the "skilled insertion of a hypodermic needle".]***	**Yes** ☐ **No** X **If "Yes", please describe the potential effects:**
19 Does this project involve a	**Yes** ☐ **No** X

series of otherwise non-regulated procedures that together may have the effect of causing that animal pain, suffering, distress or lasting harm? (For example, multiple or cumulative minor changes to the environment may cause sufficient disturbance to be regulated, even if the individual changes do not warrant regulation)	If "Yes", please describe the series of procedures and the potential effects:
20 Does this project involve any procedures or interventions on the animal(s) that is not part of its/their normal management practice?	Yes ☐ No X If "Yes", please describe the procedures or interventions: Typically, elephant keepers are always looking for new and exciting enrichment activities for their animals, so it can be argued that novel interventions are part of normal practice. For this project, we plan to introduce a system with an elephant-friendly interface, enabling the animals to control a variety of sounds. In order to use the interface, the elephants will move their trunks near or inside large objects (with no sharp edges). This kind of activity is a normal part of elephant behavior.
21 If any answer to Sections 17-19 above is "Yes", please explain the relationship between the project and The Animals (Scientific Procedures) Act 1986 in more detail	N/A *Note: The taking of a blood sample or the forceful removal of a feather to provide material solely to identify an individual, or its provenance, would not be regulated under the Act. However, the same type of sampling to provide data for an experimental or other scientific purpose (for example, to study population dynamics or to determine whether or not the animal had been genetically modified) would be regulated by the Act.* *For further information relating to the interpretation of ASPA please refer to* ***http://www.archive.official-documents.co.uk/document/hoc/321/321-02.htm#gen44***

For All Work Involving British Wildlife or Studies in the Countryside:

22 Does this research involve intentional killing, injuring or taking of animals?	Yes ☐ No X
23 Does this research involve the possession or control of live or dead animals, their parts or derivatives?	Yes ☐ No X
24 Does this research involve damage to, destruction of, or obstruction of access to any structure or place used by a	Yes ☐ No X

scheduled animal for shelter or protection?				
25 Does this research involve disturbance of animals occupying such a structure or place?	**Yes**	☐	**No**	**X**
26 Does this research involve selling, offering for sale, possessing or transporting for the purpose of sale live or dead animals, their parts or derivatives?	**Yes**	☐	**No**	**X**
27 If the answer to answer to any of the Questions 21-25 is “Yes”, please explain the relationship between this Project and The Wildlife and Countryside Act (1981) in more detail-which also regulates the disturbance of the plant environment				
	For further information on the Wildlife and Countryside Act refer to: ***http://www.naturenet.net/law/index.html***			

Ethical Approval from Other Bodies

28 Does this research require the approval of an external body?	**Yes X No ☐** **If "Yes", please state which body:-** **Blair Drummond Safari Park Ethics Panel**
29 Has ethical approval already been obtained from that body?	**Yes ☐ Please append documentary evidence to this form.** **No X** **If "No", please state why not:** **The ethics form submitted to Blair Drummond (included) requests permission to introduce an audio game to the elephants and has been verbally approved by Ally Gillies, Head Research Officer. However, formal approval is still required, when the scope of the work has been agreed.** **The concept has been discussed in detail with Brother Stefan at Skanda Vale, who has given his verbal and email approval (included).**
30 What is the funding source?	**Internal X** **External ☐ (specify)**

APPLICANT SIGNATURE

I hereby request ethical approval for the research as described above.
I certify that I have read the University's Animal Use Statement (http://www.open.ac.uk/science/lifesciences/about-the-department/life-sciences-animal-statement.php) and the Code of Practice for Research and Those Conducting Research (http://www.open.ac.uk/research/research-school/resources/research_information_and_communications.php)

Please inform the AWERB Secretary (research-ethics@open.ac.uk) if the conditions described in this proforma change after the Group has approved your research.

25/02/2015

______________________________ ____________

Applicant Signature **Date**

Fiona French

____

PRINT NAME

Approved by the OU Animal Welfare Ethical Review Body...Date....................

STRICTLY CONFIDENTIAL AND RESTRICTED

FOR COMPLETION BY THE CHAIR OF THE OU ANIMAL WELFARE ETHICAL REVIEW BODY

Please select ONE of A, B, C or D below:

☐ **A. The Faculty Research Committee gives ethical approval to this research.**

☐ **B. The Faculty Research Committee gives conditional ethical approval to this research.**

31 Please state the condition (inc. date by which condition must be satisfied if applicable)	

☐ **C. The Faculty Research Committee can not give ethical approval to this research but refers the application to the University Research Ethics Committee for higher level consideration.**

32 Please state the reason	

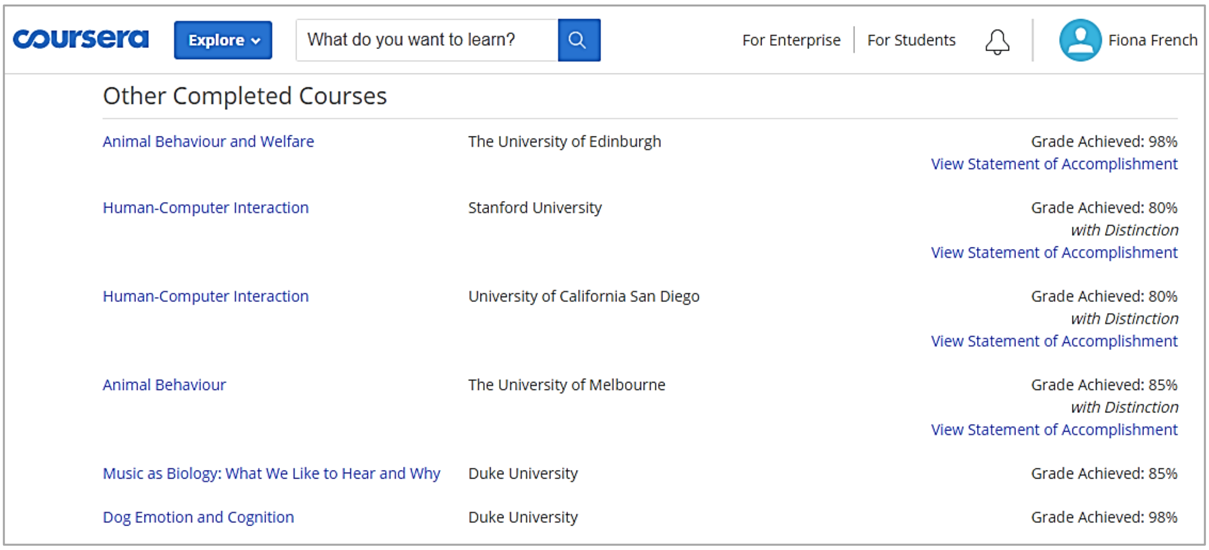
☐ **D. The Faculty Research Committee can not give ethical approval to this research and recommends that the research should not proceed.**

33 Please state the reason	

Signature of Chair, AWERB **Date**

A2: Professional Development

Relevant Courses completed (online)



Other Completed Courses

Animal Behaviour and Welfare	The University of Edinburgh	Grade Achieved: 98% View Statement of Accomplishment
Human-Computer Interaction	Stanford University	Grade Achieved: 80% *with Distinction* View Statement of Accomplishment
Human-Computer Interaction	University of California San Diego	Grade Achieved: 80% *with Distinction* View Statement of Accomplishment
Animal Behaviour	The University of Melbourne	Grade Achieved: 85% *with Distinction* View Statement of Accomplishment
Music as Biology: What We Like to Hear and Why	Duke University	Grade Achieved: 85%
Dog Emotion and Cognition	Duke University	Grade Achieved: 98%

- **Animal Behaviour** (University of Melbourne) August - Oct 2013
  https://www.cousera.org/course/animalbehav (not currently accessible)
  Assignments - weekly quizzes + write an article for The Conversation based on one of a selection of papers related to animal behaviour. I selected one on penguins.
  Overall Result: 84.8% with distinction

- **Human Computer Interaction** (University of California San Diego) Oct - December 2013
  https://www.coursera.org/course/hci
  Assignments - Quizzes + Design project from given brief - web-based service or application. Includes: Need-finding, Story-boarding, Wire-framing, Start building, Ready for testing, User testing. My app - MusicMuse - prototype melody and rhythm recall for music practice, gives user feedback on recorded input using sound wave comparison.
  Overall Result: 79.7% with distinction

- **Animal Behaviour and Welfare** (University of Edinburgh) July-Aug 2014
  https://www.coursera.org/course/animal
  Assignments – weekly quizzes. This course linked animal behaviour with the welfare of animals kept in captivity.
  Overall result: 97.9%

- **Music as Biology: What we like to hear and why** (Duke University) Feb 2018
  https://www.coursera.org/learn/music-as-biology
  Assignments – weekly quizzes. Exploration of the biological roots of music, showing how physiology and behaviour have influenced the kinds of sounds that humans perceive and enjoy. Heavy on sound theory.
  Overall result: 85.4%

- **Dog emotion and cognition** (Duke University) May 2018
  https://www.coursera.org/learn/dog-emotion-and-cognition
  Assignments – to complete with a canine companion. Explains how domestication and breeding have influenced the behaviour, cognitive ability and emotional lives of dogs; linked to a website with games/tests to perform with a dog.
  Overall result: 97.9%

A3: Meetings with Experts – EWG

2013, December 2nd

Skype meeting with BIAZA EWG (Elephant Welfare Group) members - Lisa Yon (Head, Nottingham), Ros Clubb (RSPCA), Oliver Burman (Lincoln), Samantha Bremner-Harrison (NTU) + Clara Mancini (OU) and Fiona French (Londonmet), 10-11.30am

Various points were discussed, notes follow:

Keeper feedback

One of the challenges facing zoos and wildlife parks with elephants is the "**Time Vacuum**" - there's not enough for them to do.

Lisa anecdote	% time stereotyping behaviour rose when hay net broke, so no foraging time, food eaten instantly.
Lisa -	Forum of keepers - build a dialogue, organise discussion with Elephant Focus Group, will send summary.

Interactions with humans

Lisa	emphasise more **naturalistic behaviour**; better to be **entertained** and **cognitively occupied** than to have zero interaction with humans.
Oliver	difficult to dissociate activities from human interventions.
Clara	humans can contribute indirectly.
Ros	UNPREDICTABILITY - visitors can activate, but no waiting, make sure **not visitor focused**.

Design of artefacts

Ros	give elephants CHOICE and CONTROL; make them WORK TOGETHER to reinforce social cohesion (often thrown together, not related).
Lisa	interactive with different sounds - what do they choose?
Oliver	rats' nose poke system - break IR beam, train with food, natural behaviour; CURIOSITY.
Ros	for elephants - series of differentiated holes for trunks to probe.
FF	EXERCISE... positioning of toy/game, so elephants have to move around according to some rules, PATTERN RECOGNITION.
Ros	how far do they go for different stimuli?
Oliver	might not work together, no turn-taking.
Clara	different patterns for different individuals?
Oliver	different sites, potential at each one so every elephant gets opportunity.
Ros	dominant member, bullying, social problems.
FF	is it important NOT to undermine this, or should we try?

Oliver	depends on scenario - don't do something to cause competition NO COMPETITION.
Clara	physical engagement other than walking?
Ros	must be engaging and motivating, no just walking back and forth. Wild Asian - dustbaths, wallowing, up hills, stretch to reach etc., build muscle tone.
Lisa	Meeting with keepers and engineers wrt robustness of device - how to build.
FF	earlier discussion re touchscreen...
Ros	using trunk to pull, put through hole is better.
FF	toys?
Ros	size an issue - not allowed to throw missiles!

Reward systems

Oliver	rat study - playback audio, preference for positive vocalisations; good to be doing something **not just for food**, otherwise danger of becoming **obsessive/addictive**.
FF	prefer not to use food as reward because well-designed game/toy should have **intrinsic reward**.
Lisa	also helps to **disentangle motivations**, perhaps ok for training how to use system.
Clara	if given choice, will elephants always go for a system that provides food over any other reward? At what point does another reward become more desirable than a peanut (method for testing).
Oliver	if animals will work to gain X, then X is a reward; balance time spent eating with other activities.
Ros	Diet an issue - **obesity** a problem.
FF	exercise? (design question)

Audio

FF	build a model that translates elephant vocalisations/rumbles for visitors, so they have a better understanding of what's going on in enclosure?
Lisa	depends on context, too complex...
Ros	interesting to compare sounds produced by wild/captive animals. Not possible to directly translate.
Oliver	look at context, what's consistent and reliable? We can determine positive/negative sounds, but not subtle communication.
Ros	study in US to record vocalisations in individual elephants to disentangle what's being uttered.
Lisa	interesting to compare vocalisations across groups in different facilities - is range narrower, or same as wild? In Dublin, herd structure all related, have wide repertoire.
Ros	match results to histories of elephants.
FF	comparative study beyond scope at present...
Clara	PhD focus! meaning of vocalisations is side-issue.
Oliver	do they vocalise in response to enrichment?
FF	audio capture and analysis as a means of evaluating interface design - along with other responses.

User participation

Clara	meet keepers and do observations?
Lisa	contact each zoo individually...
Oliver	need to do formally, takes time to collect and collate data
Clara	timing?
Lisa	from 2/3 weeks to 6/7 weeks

Following this discussion, we had a separate talk about ways to go forward.

- Importance of actually meeting keepers and elephants, not all research can be done online!
- HCI brings new perspective to design of enrichment activities; think about elephants as end-users.
- Strategy - build relationships with people so they'll be willing to work with us on future developments
- BY FRIDAY 6/12/13: Send ethics forms asking for consent to visit keepers and animals only, as first step - **Colchester**, Howletts, other. DONE
- BY FRIDAY 6/12/13: Send summary to Lisa so she can arrange meeting with Keepers. DONE
- Captive elephants have different life experiences - can't design one game that every animal will enjoy. Draw parallels from HCI - context is important, abstractions can be made to create an engaging experience for wide range of elephants? Develop "Set of principles" - valuable for elephant welfare + interaction design perspective; different levels of specificity, some things can be modified/bespoke.
- Compare and contrast 2 groups?
- Design framework - playful enriching interactions for captive animals. Could be a range of systems/toys - need depth for analysis, so keep number small; the toy is a means to an end - to measure, evaluate and get quantitative/qualitative data.
- How do we measure elephant preferences?
- How do we involve elephants in the design process as contributors?

A4: Colchester Questions for Keepers

Synopsis of conversation between Fiona French and Claire Bennett, the Head Elephant Keeper.

12.30pm on 6th March 2014

1. **What areas of enrichment would you like to see developed for the elephants?**

Claire: We're going to put up browse hay nets inside; have a system with pulleys and winches outside under the shelter (so we can change what's available, let different things down); a feeding wall in the rocks; a shower we can activate – and maybe also the elephants – and a wobble tree (move to push and get food, or push to relieve tension)
http://www.internationalanimalrescue.org/wobble-tree

http://boomerball.com/boomerballs/37-planet-ball-30-inch.html

http://www.youtube.com/watch?v=a88NwpxHMBg

[FF: When is all this going to happen?]

Hopefully after the sun bear enclosure is finished, in late spring.

2. **I'm interested in cognitive enrichment - creating some games/toys specially designed for particular animals. Do you think all elephant enrichment should be linked to foraging? If a game is linked to food, we won't know if they are participating because the activity is stimulating and enjoyable in any case.**

Probably, yes. You would get more reaction - they'd work harder for food. Tanya is very food-oriented; Opal not so much. She's lazy.

3. **I've watched elephants playing with mud, spraying dust and interacting with each other - not related to food, but seems to be fun. What other things do they enjoy that I haven't had a chance to observe?**

I think you've mentioned everything… Zola and Tembo love each other! Sometimes they do trunk wrestling, they do play-fights. (2 weeks ago, Tembo mated Zola – very exciting news)

[He's so gentle with her]

Oh yes.

[I enjoy watching them in the mud, but I never see them in the pond or under the waterfall.]

No, African elephants don't go into the water, except sometimes in summer. Indian elephants like to play in water, but Africans love the mud.

4. Would you like to use a game/toy WITH the elephants, or allow elephants to use it independently?

(POSITIVE) Ideally, we would like to spend more time with the elephants. It depends on all the other work commitments – cleaning etc – that we have. The more time we spend with them, the better, so maybe.

5. Sharing and competition - do you think elephants would cooperate to do something? Would something new in the enclosure cause competition or unwanted stress?

(POSITIVE) I think they would cooperate. Tanya is dominant and also very intelligent. She would make Opal help her and then take all the browse at the end. Tembo just breaks things. Something new shouldn't be a problem. Tanya might be competitive, but she's not aggressive.

(Other keeper also overheard talking about elephants cooperating to solve a puzzle; citing Plotnik research http://thinkelephants.org/documents/PNAS2.pdf; comments that they have preferred keepers and conspecifics for particular activities)

6. Daily rhythms - is it better to stick to established patterns or to provide surprises?

Both. We have to keep to routines for feeds and elephant encounters. It's good to change things a bit with enrichment. Opal is the only one who doesn't like a change in routine.

7. Usually, games give people opportunities to make decisions that have an effect on the game - controlling what happens. For Animal Computer Interaction, the challenge is to find an interface for the animals to use in order to have some control over a system. The feedback mechanism has to be something motivating for elephants.

[What to control? AUDIO / VISUAL / CHEMICAL / TACTILE / MOTOR
Audio seems interesting (+ infrasound) and relatively easy (for programmer) to develop. Choice of sounds?]

(POSITIVE) Agree, that would be interesting.

[Can we take over the loud-speakers?]

We'd have to ask the zoo managers.

[Advantage is that the tech would be on one side of wall and elephants on the other. We can generate infrasound, currently investigating ways of capturing it but there might be too much noise interference.]

You can tell when the elephants are making it, because the top of the trunk wobbles, and when you're standing next to them, you can feel it.

[Can you feel the ground vibrate?]

No it's different, it's almost in the air.

[How often do they do that? Daily?]

No, not often. If they've been separated for a while and they see each other again.

[Because we can generate it, perhaps we could use it and get them to distinguish pitch… Perhaps they could vocalise the correct pitch themselves to activate something…]

Yes, that might be good.

[Not sure about elephants' visual acuity? Would require expensive screens. Humans don't understand enough about smells so a solution would be very crude.]

Agree, we tried spices, but they weren't interested.

[You've suggested a boomer ball might be fun to play with, but could it be manipulated to control something else? Elephants not known for extensive tool use.]

(POSITIVE) Yes, probably they could, I don't see why not. They'd work it out.

[Motorised device (eg. peanut dispenser) easily broken? Activate a hose to release water? Direct a hose? This is similar to what you are already proposing to do… would you let elephants make their own mud-bath?]

(POSITIVE) Yes, we were going to have a sensor or a pad to activate, we could do it as well as the elephant.

[How to control? REMOTE SENSING / PHYSICAL CONTACT
Again, remote sensing avoids problem of manufacturing something robust. Eg. a hole in the wall with a beam-breaker, activated when trunk goes in; Kinect sensor (elephant would have to be in vicinity).]

(POSITIVE) They wouldn't have a problem putting trunk into an object.

[We could do something low-tech first, see if they would put trunk into a bucket for a peanut, then they'd know what to do.]

They wouldn't have a problem with that.

[Big objects (lever, pulley, handle etc) could be fun to manipulate, but possibly more difficult to make. What about pulling a rope?]

(POSITIVE) Oh yes, they would do that…

[Where and when to use? OUTDOORS / INDOORS / AVAILABILITY
What do elephants do after hours?]

After hours… they eat. The food generally lasts until 9pm, then they doze. Sometimes they lie down for a while, mostly Opal. Tanya and Opal are together in the large area, Tembo and Zola stay in their respective pens, for safety, no stress etc.

[Does someone monitor their behaviour overnight?]

We used to have someone here. I stayed when we allowed them access to the paddocks overnight in the summer when it was hot. We have cameras, but they're broken at the moment.

[Could be used to encourage movement around enclosure…]

(POSITIVE) That would be good. They need more exercise.

[Are there any power points around the enclosure?]

I think there's one up by the elephant statues.

[Might incite curiosity if offered for fixed period at limited times (would also enable me to observe reactions)]

(POSITIVE) Yes, it would be easier to have a set time to do something, just for a part of the day.

[If we could develop an application that enables the elephants to have some control over their environment, but is not a game/toy, that would still be great and fall within scope of Animal Computer Interaction. Ideally, I would also like to develop a similar system that humans could try to operate (perhaps on a smaller scale, perhaps virtual) to give visitors a shared/simulated experience.]

(POSITIVE) That might be interesting, give the visitors some insight into elephant behaviour…

[A couple of other questions – what's the white stuff you put on their ears?]

Udder cream. Sometimes elephants in cold climates get frostbite, so that keeps the ears from becoming dry.

[How do you clean and maintain Tembo and Zola since you don't have direct contact with them?]

Always on the other side of a wall/bars. They're protected contact, so we never stay in the same space as them. They are target-trained to cooperate and they usually do. The main difference is they can choose to walk away, but the other two must obey (safety).

[We would aim to do something very low tech to start with. I would put everything in another ethics form first.]

Yes, that's the way to do it.

[Thanks very much for your time.]

A5: SHAPE Environmental Enrichment Course

Student Environmental Enrichment Course (S.E.E.C.) (The Shape of Enrichment) Aug 2014 http://www.enrichment.org/miniwebfile.php?Region=Workshops&File=seec.html&File2=seec_sb.html&NotFlag=1

This section is an account of the SHAPE course undertaken in August 2014, written just after the event. It includes lecture notes, detailed descriptions of workshop activities and explanation of context.

Student Environmental Enrichment Course

Presented by The Shape of Enrichment at Lakeview Monkey Sanctuary, 4-7th August 2014

Overview

The course was run by Mark Kingston Jones and Chris Hales. My previous contact with Mark was in June 2013, when he worked as Educational Officer at Howletts and I contacted him with regard to research into cognitive enrichment for elephants or other species. Howletts subsequently made redundancies in their Educational section and Mark is working both independently and for Shape.

Lakeview Monkey Sanctuary (http://www.lakeviewmonkeysanctuary.co.uk/) is run by Jim and Sharon Shaw. It is usually closed to the public, but it hosted the practical aspect of the enrichment course. Jim and Sharon are both ex-zoo keepers who started a sanctuary over 30 years ago and have relocated to a site with extensive woodland in Bucks (near Ascot). All their monkeys are rescued - from labs, domestic environments and some wildlife parks/zoos. As the animals are nearly all highly strung and in need of peace and rehabilitation, public access is inappropriate.

The course consisted of lectures, workshops and a group project, which was to design and build enrichment for some of the primates at the sanctuary. The following sections provide a summary of the skills and knowledge acquired over the four day period, with a longer description of the practical aspect, during which it was possible to become completely involved in all aspects of design and development, working alongside keepers and other students. This "action research" was extremely useful, offering me the opportunity to focus on a specific problem (we were given a clear brief) and experience both the challenge of developing a solution and the reward of observing the enrichment being used.

Practical zoo-keeping and breaking into the zoo world

This aspect of the course focused on the skills that zoo-keepers should try to develop and a description of their roles - primarily cleaner, but also gardener, builder, carpenter, chef, butcher, pest controller, nutritionist, health care professional, veterinary assistant, mortician, record keeper, teacher, behaviourist and sometimes animal trainer. Essentially, the role combines conservation with education and research, glued together with a programme of entertainment (enrichment). The recommendation from the tutor was to try and develop observational skills and an "animal sense" - knowing how the animal feels using intuition. Other requirements were good organisational skills, the ability to be creative and innovate, to show compassion and empathy, and to demonstrate a desire to learn.

Enclosure elements

When designing enrichment, there is often a tension between safety and stimulation. The more exciting the enclosure is for the animal, the more risky it necessarily becomes. "By definition, an enriched environment offers more potential for harm than a sterile environment. Yet, the behavioural, physical and welfare benefits of providing an enriched environment are generally considered to outweigh the risks." (Hare, Rich and Worley, 2008, http://www.enrichment.org/MiniWebs/About_EE/hare_2008.pdf)

Some relevant questions include: Should an enclosure be open-topped or enclosed (by fencing)? Aesthetically, an open-topped enclosure seems better to the public as it appears to allow more freedom and animals have an unrestricted view of the sky. On the other hand, a top provides protection from predators such as kites and climbers really like the roof, which becomes usable space. Similarly, should the enclosure have a moat but no cage walls? This allows public to view, but the buffer reduces the size of the enclosure by a greater amount.

It is important to remember that animals need some shelter to protect them from being seen all the time, otherwise they may become stressed.

Knowledge of animals' natural behaviours is key. For example, male bison dust-bathe to control pests, but they also dust and display to determine seniority, thus avoiding fights. Therefore it becomes very important to allow them to express this behaviour. Elephants need a bathing area big enough for them to be able to submerge - but this also becomes a risk if a baby falls in before it has learned to swim. The gorilla enclosure at Howletts Wild Animal Park is not pretty and does not have a naturalistic appearance, but it works really well for the animals, providing many opportunities for climbing and playing.

Animal Welfare

"Enrichment is a dynamic process for enhancing animal environments within the context of the animals' behavioural biology and natural history. Environmental changes are made with the goal of increasing the animals' behavioural choices and drawing out their species-appropriate behaviours, thus enhancing animal welfare." (1999 AZA Behaviour Scientific Advisory Group)

The course covered the Five Freedoms and then elaborated these into the following 12 Freedoms, with recommendations for associated enrichment:

1. **Good feeding - absence of prolonged hunger**.
   Recommendations: Try different ways of presenting food – this is species specific, so an appropriate research is required. Scatter feeds are good, but it is important to be careful that wild birds do not eat it and to check the correct quantity. Carnivores like chunks; wild dogs feed in groups, tearing apart a carcass – their canines need working to remain healthy (note jelly/pellet cat food for pets is not a great idea); bone is a source of calcium, while fur etc cleans the teeth. Chris and Mark explained their simple yet extremely effective concept for an ice-feeder, which melts overnight so that food is slowly revealed for a night-time feeding opportunity.
   Example: the domestic horse is a grazer/trickle feeder and also a herd animal, therefore sociable. Browse – leaving hay in field is better than using a feeder, so everyone gets a share and they can be sociable if they choose.

   Live feeding is prohibited in the UK – so do not put bird feeders in the big cat enclosure!

2. **Good feeding - absence of prolonged thirst**
   Recommendations: Again, use a variety of presentations - eg. waterfalls, pools, fruit-pops. Many grazing species gather round a waterhole to drink, which is an opportunity to take turns being on look-out, therefore enhancing another natural behavior.

3. **Good housing/environment - comfort around resting**
Recommendations: Research what the animal needs. It is vital to provide different substrates - straw indoors, peat floor. It may be tempting to arrange all the nesting material into a cosy bed, but in fact, it is much more enriching if the straw bale (for example) is left for animals to arrange by themselves, as they would in the wild.

4. **Good housing - thermal comfort**
Recommendations: Example: the Malaysian tapir lives in tropical lowland rainforests; their young can die from respiratory problems in captivity, due to poor ventilation or lack of exercise. It is too cold for outdoor housing in winter so circulate heating with fans/heaters/water to provide humidity, optional showers and fresh browse.

   Provide access to outside yard so the animals have choice - EMPOWER the animal to make up its own mind.

5. **Good housing - ease of movement**
Recommendations: Example: Cheetah - Chris constructed a zip-wire, using a bulldog clip for hanging meat, a track runner with a tandem pulley and karabinas. This made her chase her food for the length of enclosure.

   Example: the clouded leopard is usually solitary; the male decapitates female (!) when they are housed together. It is important to allow her to escape by providing thin branches that the male is too heavy to use so she can return to her own adjacent enclosure.

6. **Good health - absence of injuries**
Recommendations: Safety first! Cut down all frayed or worn rope, look out for nooses, heavy suspended things, fallen strings or wire for tangling, sharp bits and danger of trapping fingers (public may be at risk too). Example: tigers – use a pulley system for raising meat up pole feeder, avoiding injury to a keeper on a ladder.

7. **Good health - absence of disease**
Recommendations: Animals require regular health checks and treatment when needed. Beware spread of disease – it is a useful idea to colour-code enclosures to tell who was last in/whether cleaned yet etc. Aim to keep animals fit and healthy with low stress levels and a good immune system by providing species specific enrichment.

   EXERCISE: The way bones and muscle structure grows has a lot to do with exercise; non-stimulated animals will be badly developed and have problems later in life; the skeleton renews itself once every 3 months (healing time). Exercise makes the heart pump, increasing endurance and stamina, also reduces fat, contributing to a longer, healthier life. "Talking to various vets, most agree that a couch-potato lifestyle does indeed lead to joint problems." (Dr Andrew Kitchener, Principal Curator of Mammals and Birds for National Museum of Scotland.) Example: lions usually hunt; the introduction of a spring-loaded pole feeder makes them work muscles and have healthy marrow (where blood is created).

8. Good health - absence of pain induced by management procedures

Recommendations: Example: bongos have a pre-programmed flight distance – if a bongo is scared, it could run straight into a fence, so make the enclosure long and narrow.

Example: the horse is a prey species, therefore learns all about its environment. That is why a novel paper bag in the hedge can cause alarm, so be careful about arbitrarily changing something in its enclosure.

“True enrichment rectifies brain function, reduces fear and frustration, and improves welfare.” (Dr Georgia Mason) A non-stimulated animal will become stressed; cortisone, a glucocorticoid, and adrenalin are the main hormones released by the body as a reaction to stress; one of cortisone’s effects on the body is the suppression of immune system which in turn leads to illness or inability to heal as fast (known as immunosuppression). Therefore, animals treated by a vet may heal faster when reintroduced to their group instead of being left in a new environment (treatment room) with new smells etc.

9. Appropriate behaviour - expression of social behaviours

Recommendations: Find out what is normal behaviour for these animals – eg. gorillas, African wild dogs, lions, primates, elephants, wildebeest… For example, sparring may be appropriate behaviour at certain times of year - as long as animals have sufficient space so that one can drop out. “Animals living in the wild are not without stressful experiences.” (Sapolsky 1990) We expect meerkats to be on sentry duty or hunting for bugs - if feeding time is regular, they will all stop watching in order to be fed, therefore it would be better to vary the times. Flamingos like to be in large groups, so use mirrors!

10. Appropriate behaviour - expression of other behaviours

Recommendations: Use enrichment! There is scientific evidence (REF?) showing that rats in enriched environments have larger brains compared to those in barren environments, and a much larger hippocampus (spacial memory).

Example: birds have different behaviours and adaptations, such as migration. Are enclosures large enough for animals with this natural behaviour? How is it possible to simulate travelling distances? Hot and cold features may give a sense of different locations, so try to create thermals. Feeding - scatter feed, hide stuff, create the need to peck a box, provide pipe feeders for ibis (who stick long beaks into mud). Example: primates should have opportunities for climbing and tool manipulation. Example: elephants like to have dust baths using their trunk.

“Zoos should aim to make captivity stimulating for their animals, and in species appropriate ways. The physical and social environments of animals living in their natural habitats are dynamic and may change randomly and unpredictably, and so captive animals need to be challenged in order to lead a good life.” (Sachser, 2001)

"The captive environment may not look naturalistic when compared with the wild (for example, because of cage bars), but the functionality of the wild environment and the opportunities for a normal range of behaviour can be mimicked to a degree in captivity, a key quality for good welfare." (Hill and Broom 2009)

Note: Sometimes normal behaviour may look like stereotypies and vice versa. Big cats patrol, and this is not necessarily pacing; ostriches do a repetitive mating dance. Is the animal grooming or barbering? The Coati head toss may be mistaken for playing.

11. **Appropriate behaviour - good human-animal relationship**
    There was a discussion within the class of hand-rearing and whether it is ever appropriate. There were mixed opinions on this, with some people favouring this and others feeling that it panders to a human need to nurture and have physical contact without providing any benefit to the animal.

12. **Appropriate behaviour - absence of general fear**
    There is evidence that enrichment improves resilience, by enhancing coping abilities to stress. "Socially housed rats are more resilient to stressors than single housed rats." "Enrichment reduced the heart rate response to handling in single housed rats - habituation to stressor happened much faster." (Dr Georgia Mason)

    Recommendations: Make sure your enrichment is not the cause of any distress. It is also important to consider public perception of welfare - people may need to be educated.

The following questions should be the ones that keepers continually ask themselves:

- Are the animals in our care fit and healthy?
- Do they have what they want and need?
- Are they happy?
- Are they mentally stimulated?
- Do they have the correct environment?

Categories of enrichment
"Play is a hallmark of good welfare." (Mark Kingston Jones 2014)

Social
- Conspecifics have natural groupings. Strength / safety in numbers - fish - rays play with a ball in tank (eventually). Some animals prefer to be solitary - polar bear. Others can form bachelor groups (if it's usually an alpha male + many females in the group).
- Groupings can be formed with mixed species, but not predator and prey. Other side of fence species - toys linked with rope. Remember to provide choice about how much social contact.
- Play is important.
- Mating behaviours - eg. show of strength, ability to choose one's mate.
- People – training animals for PC.

- Faking it; mirrors - use sparingly. Plush toys for grooming practice if you're lonely; flying foxes have hanging teddies in mating season to avoid lots of urinogenital injuries. Fake deer to spar with.

Cognitive

- Mental stimulation - not just puzzle feeders! Touch screens, novelties, hiding stuff (where's my water pool?), problem solving barrel feeders (for tigers, lobsters, primates), kerplunk.
- Shaping behaviour with training
- Lion Rover, prey simulation
- Marmosetcare.com - shows marmosets observing and finally attacking a toy spider.

Physical habitat

- **Refuges**: Cats like to be elevated so they can observe the world; goats also want an chance to jump above stressors. Many animals need places to hide; using different senses, so a clear plastic bottle can be inside a tank for a fish to "hide" in while public can view. Internal visual barriers need not be big, as small animals disappear easily - out of sight, out of mind; external visual barriers to stop public being so scary. See Edinburgh aviary for effective permanent external barriers/ viewing windows. If you don't use them, you lose loads of space by the edge. If the animals feel safe, people are more likely to see them.
- **Substrates**: Access to appropriate materials is required, including materials they don't necessarily need, for playing and hiding (straw, piles of sand) A choice of resting places is good (hammocks, platforms). Allow them to dig their own dens. Water elements are great - for elephants washing, for tigers swimming, for hammercocks (bird), for seals etc. Expressing natural behaviours, but also for play - bubble baths and video of cat flushing toilet multiple times - in control!
- **Climbing structures**: Variable terrain - baby elephants CHOOSE to go over the hills and bumps, contra-freeloading = not always electing the easiest option, animals prefer to work. Wild dog pups can climb trees, lemurs like bamboo, gibbons are brachiators. Different textures, diameters and angles (not all 45 deg) are good; dynamic branches and swings for motion; viewpoints.
- **Climate gradients**: There are seasonal variations in UK, which can be fun (snow), but some animals need constant access to heat and light; others require shade and dark; others need humidity.

Think about the GOAL behind what you are putting in.

Sensory

- **Tactile features**: balls, rocks, floating logs, cushions, substrate piles, astroturf and firehose craft, snow, grass cuttings, sacrificial planting.
- **Olfactory**: herbs - scent boxes, objects that another animal has been inside (leaving scent marks), both natural (orange peel) and unnatural (plastic containers, Calvin Klein perfume for big cats).
- **Auditory**: the least used enrichment… be careful - infrasound played to elephants at Howletts had a bad reaction, scared everyone and made the bull charge! Wind chimes and noise makers, also acoustic barriers such as trees and shrubs, to stop sound (of kids) being stressful.

- **Visual**: food colouring on snow, bright feathers (what is that?). Pirhanas hang out with red toy. Bubbles = moving stimuli (rc cars). In wild, tropical storms sweep sky, water moves. People are a potential moving source of enrichment as well.

Food

- **Novel items**: seasonal food for its value as an investigatory enrichment; novel items such as fruitsicals (ice lollies); also physical and mental stimulation (woodlice in a log). Sometimes food is not nutritionally important, but can still be fun - eg. left-over pumpkins from halloween.
- **Presentation**: Animals don't just get handed food in the wild, they have to work for it, using time and/or energy. Try to encourage specialised feeding/foraging behaviours - may require physical adaptations - feeders etc on bars. CONTRAFREELOADING = animals prefer to work for their food, an argument against people who say "it's not fair" to hide supper. The same amount of food gets eaten, regardless of the amount of time taken to acquire it (and it gives them something to do).
- **Feeding behaviours**:
    - Foraging: (1) recognise food, (2) find food, (3) obtain food, (4) process food. Throw away the bowls! Or make them more interesting.
      (1) Scents are important to enable recognition of food; visual - fish only fed from white end of pipe remembered this a year later!
      (2) maze/puzzle feeders (different animals have different abilities);
      (3) obtaining food - chase, catch, kill - laser pointer for domestic cat enrichment; helium balloon monkey filled with spag bog for chimps to attack (lab animals). Browsing high and low to stretch muscles, climb and grab and jump and dig up…
      (4) processing food - don't pluck or skin, whole fruit, veg, carcass.
    - Fill time and expend energy: scatter, bury, pinatas and boxes (made by school kids), ball feeders, kongs, barrels, spiked food, basket and willow ball feeder (edible material used to make it), drilled logs, kebabs and tube feeders outside enclosure (easy to fill). Problems for raccoons - doors, drawers and knobs; cage-top feeding.
    - Live feeding - spectator sport? No chance to escape, always a moat or electric fence, what about the welfare of the prey? Look after prey animal welfare too. Every bit of food your animal receives is an opportunity for enrichment and/or training - do not waste it!

Personalities are different - not all animals like the same food. Allow everyone in the group to participate; variety is the spice of life; LISTEN to your animals!

Workshops

Clicker training

We learned how to use a clicker to train, by training each other soundlessly. The objective was to use only a click (or no click) to get another person to do what you had in mind. It was assumed that positive reinforcement with the clicker had already taken place. The exercise was challenging and frustrating and amusing for both sides, but ultimately enlightening.

Definitions: Learning = "the act or process of acquiring knowledge or skill"; in psychology = "the modification of behaviour through practice, training or experience".

The important question to ask is: "When do animals learn?"

Fire-hose

This was a workshop showing how to use old fire-hose to make features for enclosures.

Figure 1: Different methods for weaving firehose into hammocks (Aug 2014)

Rope splicing

This workshop demonstrated different splicing methods for various applications - ends, eye-holes, joining two sections of rope.

Team simulation

Team could choose from the following enrichment goals: (1) lion enclosure; (2) gorilla cognition; (3) rhino anything.

We had to brainstorm ideas and present them to a head keeper. For the rhino, the team suggested:

- somewhere to wallow
- moving target to charge
- mix species - add other animals
- pinata targets
- bird feeders to stick on back for the birds that stand on them
- total wipeout for rhinos
- mud statue - built by visiting kids (because they like snow)
- apple bobbing
- circuit training - pushing against the crowd
- mirror

Feedback we received was that we are not allowed to mix species as no other species would stay in rhino enclosure (they could escape); it would be too expensive and difficult to make a pool. The main lesson to take away from this:

WHAT IS YOUR GOAL?

Enrichment design process

Context: Lakeview walk and talk

Jim and Sharon took everyone round the sanctuary and told us about their history. It costs around £1000 per monkey per year to look after all the animals. As there is no public access, it's difficult to raise sufficient money.

Figure 2: Looking round Lakeview Monkey Sanctuary (Aug 2014)

They are planning to test Zoopharmacognosy (self-diagnosis and medication behaviour by animals) in near future in an effort to stop some of the recurring health problems (eg. fur loss).

Independent research

Capuchin

The two capuchins are Gizzy (f) and Davidson (m), both ex-pets.

- There are two species of Capuchin, gracile (longer limbs) and robust; they probably diverged when the Amazon split the country.
- Varied diet - spiders, insects, nuts, fruits, seeds, eggs.
- Time budget - 80% foraging.
- Spend time in trees, only to ground for water; diurnal, sleep in branches.
- Predators - harpy eagle, potentially jaguar, crocodile, snakes.
- Social - usually large family groups with dominant male, sometimes a dominant female too.
- Innate stone-bashing behaviour (to crack nuts); some have learned to bash rocks to ward off predators with the sound and taught this to their offspring; some have been observed watching hornbill behaviour, then selecting ripest fruit and piling up on forest floor, travelling 1km to collect stones and using on dried nuts 2 days later.
- Intelligent and easy to train (except house-training). They are common companion animals for quadriplegic people in US. Popular pets until age 2, when they mature and change personality - can bite, scratch etc.

Macaque

The three macaques - Baloo (m), Bacill and Bacillusk (f) - are ex-laboratory animals.

- They are the most widespread primate, 22 species, Old World monkeys
- Rhesus macaque used a lot in animal testing – viruses and visual perception – can discriminate colours
- Many carry Herpes B and Simian Foamy Virus
- Recent news – crested black macaque selfies!
- Japanese macaque – males bigger, females spend more time in trees
- Great swimmers
- Matrilineal society, several males and females in groups with males moving between groups
- Females do lots of grooming for hygiene and to maintain hierarchy
- In some groups, older males also do parenting
- Play - Northern macaques love snowballs
- Time – 23% travelling, 24% feeding, 29% social grooming, 20% inactive
- Omnivorous
- The three wise monkeys and the monkey in Chinese Zodiac were macaques

- In captivity – enrichment could be swimming pool, visual barrier, swings (arthritis a problem for older macaques)

Brainstorming

Two teams had two briefs - foraging enrichment for capuchin monkeys, environmental enrichment for macaques.

I chose to join the environmental enrichment team. Ideas included wind chimes, rain-maker, beads-on-wire toy, giant pepper pot seed shaker, umbrella with hanging bells, giant robot tortoise on wheels, controllable shade…

Figure 3: Brainstorming (Aug 2014)

Finalise and design devices, review ideas

The following ideas were signed off by the keepers, shown with the resulting devices.

Dynamic branches

Mark and Chris advised that dynamic branches should be part of our enrichment for the macaques. The branches are not fixed, but swinging, as real tree branches would. They are connected so that movement on one affects the others. They require use of more muscles and balance.

The team salvaged fallen wood from the forest and used rope splicing techniques to suspend the branches from fire-hose tethers.

Figure 4: Building dynamic branches

Herbal fairy-lites and hammocks

Fairy lights (firehose boxes) are for olfactory stimulation. Members of team brought fresh herbs (coriander, mint, rosemary) to fill the fire-hose boxes they constructed.

Figure 5: Firehose boxes filled with herbs

Acoustic seesaw

The seesaw is connected to the dynamic branches, so that when an animal moves along it, the branch is disturbed. The rainmaker is supposed to run along the side, but the seesaw never reaches sufficiently large angle for the irregular pebbles to roll. We put the rainmaker on one of the dynamic branches instead.

Figure 6: Putting up the dynamic branches

Instead of a tyre, which was too tough to cut with our equipment, and too big to bury in the time available, we rolled more fire-hose and made a smaller version. Wood was salvaged from forest and surrounding site.

Enrichment in

The occupants were temporarily locked in their indoor homes while we fixed all the enrichment devices.

Results and conclusions

The most amazing part was observing the macaques and the capuchins exploring their space and investigating the novel features.

The macaques spent half an hour cooing to each other as they explored the space and tried different things.

The dynamic branches were clearly surprising for these macaques, not used to feeling anything move under their paws. Hessian rope, on the other hand, was well chewed. I was particularly excited to see the seesaw being explored by Baloo.

All the hammocks we made seemed very popular (the fire-hose workshop examples were quickly installed in other enclosures). We also attempted a wind chime, made from drainpipes, which made an interesting rattle.

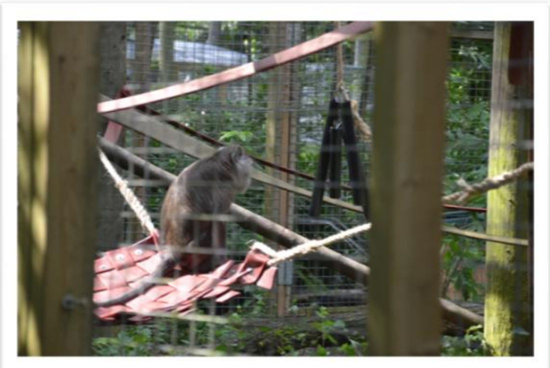


Figure 9: Sitting on a hammock in sunshine

Figure 8: Chewing hessian on a dynamic branch

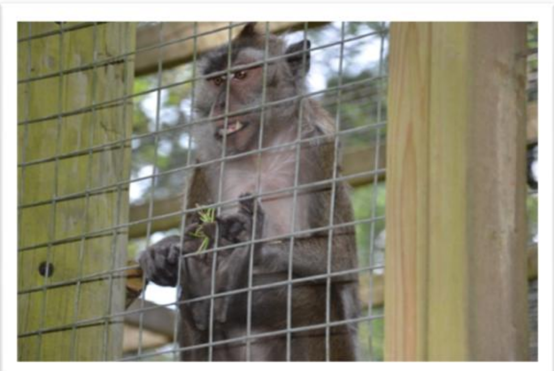


Figure 7: Macaques like rosemary

In conclusion, our work designing and developing enrichment devices was a success, as evidenced by the animals exploring the new equipment and showing an interest in the features. The goal for the capuchins was to encourage foraging behaviour, and they clearly used their time and energy to locate and extract food from the various locations. The goal for the macaques was to provide environmental enrichment that was not associated with food, and all three animals explored the new features, smelling, touching and using balancing skills to navigate the new branches and swings.

The keepers, Sharon and Jim, were delighted with the work and will welcome more students to undertake environmental enrichment courses on their premises.

A6: Ethnographic Data

This section contains examples of the documentation created during the ethnographic study conducted at Colchester Zoo from January to May 2014. Some of the data includes single visits to Howletts in March 2014, Skanda Vale in October 2014 and Blair Drummond in February 2015, as well as two visits to Colchester outside this time period.

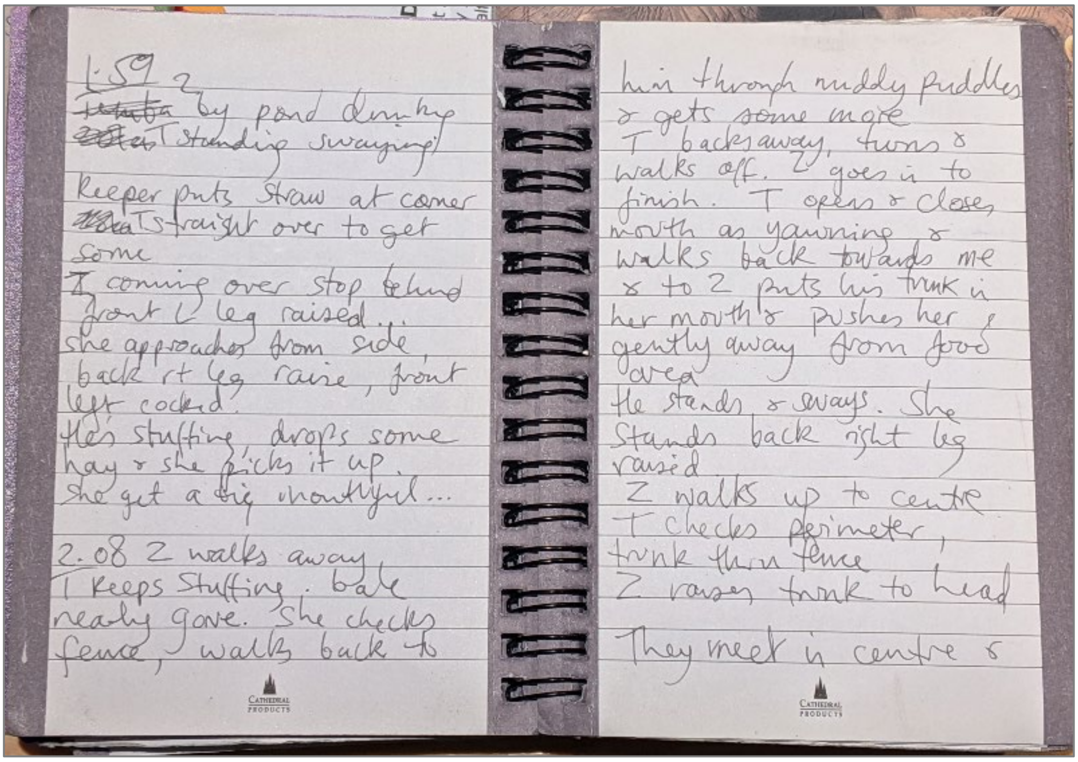
Figure 1: Sketches of Colchester elephants, 2014

The behaviours recorded in writing were also captured in over 100 still photographs and over 200 short video clips, comprising over three hours of filmed material in total (see Figure 2: Overview of media data). Several of these photos and video stills are used to illustrate the text in *Chapter 4: Understanding Elephants – Ethnographic Study*; some are used in *Chapter 5: Design and Craft – Workbook: ideation and Production*.

At Colchester, observations and drawings were initially recorded by hand in notebooks (see Figures 1, 3, 4). Notes were then recorded formally in a spreadsheet, at which point specific behaviours were categorized and highlighted (see Figures 5, 6).

OVERVIEW	Location	Date	Footage ethnography	Clips	Pix ethnography
	Blair Drummond	Feb-15	00:03:32	5	13
	Skanda Vale	Oct-14	00:13:32	12	12
	Colchester	May-14	00:06:15	8	7
	Howletts	Mar-14	00:25:47	19	10
	Colchester	Mar-14	00:26:57	24	4
	Colchester	01-Mar-14	00:43:13	39	6
	Colchester	20-Feb-14	00:22:44	16	1
	Colchester	19-Feb-14	00:09:57	8	5
	Colchester	05-Feb-14	00:06:16	10	13
	Colchester	29-Jan-14	00:08:29	13	3
	Colchester	22-Jan-14	00:21:00	13	21
	Colchester	08-Jan-14	00:13:08	13	17
	Colchester	Aug-13	00:02:50	23	32
TOTAL			**3:23:40**	203	**144**

Figure 2: Overview of media data

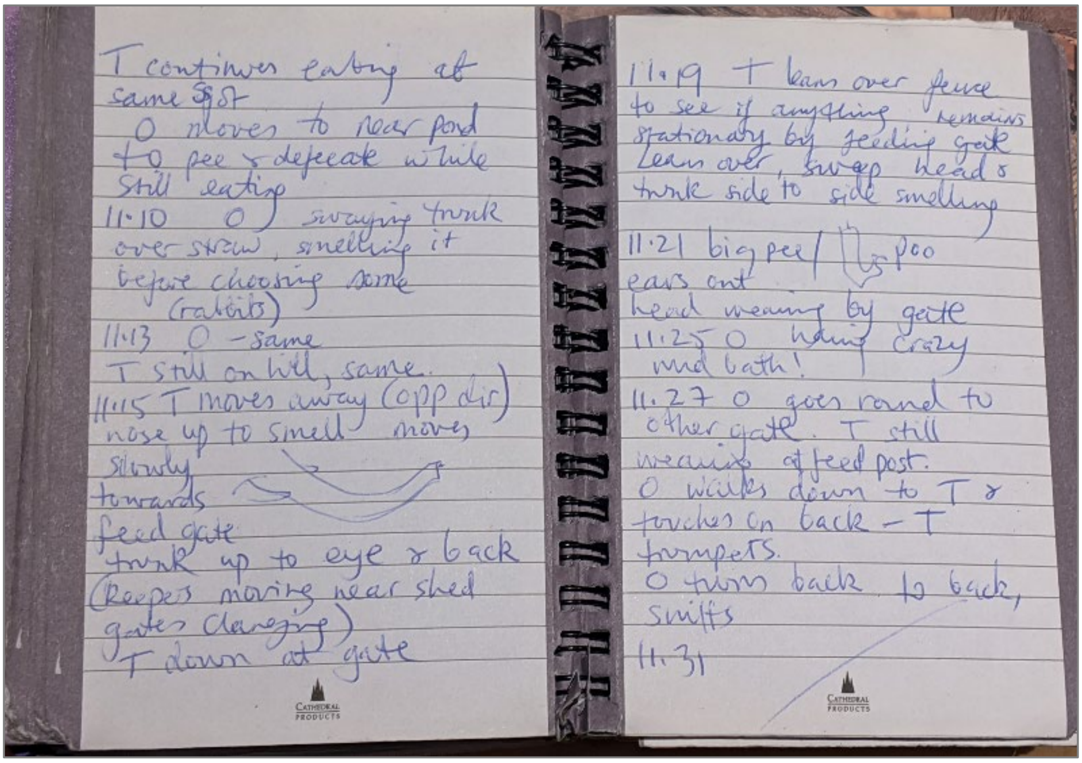

1.59 Z
by pond drinking
T standing swaying)
Keeper puts straw at corner
T straight over to get
some
Z coming over stop behind
front L leg raised...
she approaches from side
back rt leg raise, front
left cocked.
He's stuffing, drops some
hay & she picks it up.
She get a big mouthful...

2.08 Z walks away
T keeps stuffing. bale
nearly gone. She checks
fence, walks back to

him through muddy puddles
& gets some more
T backs away, turns &
walks off. Z goes in to
finish. T opens & closes
mouth as yawning &
walks back towards me
& to Z puts his trunk in
her mouth & pushes her
gently away from food
area
He stands & sways. She
stands back right leg
raised
Z walks up to centre
T checks perimeter,
trunk thru fence
Z raises trunk to head

They meet in centre &

Figure 3: Notebook observations of Tembo and Zola, Colchester Zoo 2014


T continues eating at
same spot
O moves to near pond
to pee & defecate while
still eating
11.10 O swaying trunk
over straw, smelling it
before choosing some
(rabbits)
11.13 O - same
T still on hill, same.
11.15 T moves away (opp dir)
nose up to smell moves
slowly
towards
feed gate
trunk up to eye & back
(keepers moving near shed
gates clanging)
T down at gate

11.19 T leans over fence
to see if anything remains
stationary by feeding gate
Lean over, swap head &
trunk side to side smelling

11.21 big pee / poo
ears out
head weaving by gate
11.25 O having crazy
mud bath!
11.27 O goes round to
other gate. T still
weaving at feed post.
O walks down to T &
touches on back - T
trumpets.
O turn back to back,
sniffs
11.31

Figure 4: Notebook observations of Tanya and Opal, Colchester Zoo 2014

	A	B	G	H	I	J
1						
2	TIME	*ENVIRONMENT*	ZOLA		TEMBO	
3						
6	10:55:00	*rabbits, crows, seagull*	feeding together by lake, same pile of straw		feeding together by lake, slightly aroused	
7			She moves away		balancing on edge of pond, has erection, moves towards Z and reaches to her tail	
8			walks to oppostie side of pnd, anticlockwise, drinking		walks clockwise rund pnd to eat more hay	
9	11:10:00		drinking		foraging hay at side	
10			moves away from water		sniffing poos, does large poo and wee	
11			turns anti-clockwise circle then moves to fence; back round towards T then off and round to original space by water/hay		continues eating near poos	
12			balancing on 2 legs		continues eating	
13			turns to look at me. I wave, she snorts and flings trunk to one side.			
14			looks at me, I wave, she turns away and continues to graze		continues eating	
15					sniffs own poo, walks carefully over other poo (not treading) down trail to corner	
16		*rabbits all over the hay*	feeding by pool		investigating edge of muddy puddle, reaches through fence bars	
17			moves over to stare at me again then goes round to feed at T's spot		starts weaving by fence, flaps ear	
18	11:25:00		back right leg up, feeding		waves and scratches right ear, feels own leg, continues weaving, scratch right leg	
19			scouring surface of forage spot (sweeping trunk)		weave and flap right ear, snort	
20			moving away, does more poos by her poo pile (more solid than his)		swaying, right back leg bent, looks awkward, adjusts stacne	
21			back right leg raised, continues eating		flaps ear, swaying	
22			forage past raised platform, paws ground investigating something		same behaviour, swaying, curl trunk, feel leg	
23	11:40:00		head down in muddy hole, still eating and investigating		same	
24			something in hole, trunk inside mouth for 2 min - drinking?, head down		same (still swaying)	
25	11:55:00		still busy with hole		same	
26						

+ ≣ 8 Jan 2014 ▾ 22 Jan 2014 ▾ 29 Jan 14 turn ▾ 5 Feb 2014 ▾ 19 Feb 2014 ▾ 20 Feb 2014 ▾ 14 May 2014 ▾

Figure 5: Example observations of Zola and Tembo, showing simultaneous behaviours. Recorded from 10:55 to 11:55 on 22 Jan 2014.

	A	B	C	D	E	F
1						
2	TIME	*ENVIRONMENT*	TANYA		OPAL	
3						
4	muddy, clear, sunny, cold					
5	13:00:00		Foraging hay from wet ground, dust it on inner trunk	still / feed	Searching in wall for food, clambers over rocks	feed, scramble
6			Walks to spot by pool	walk	Forages for straw on ground	feed, scramble
7			Moves back up to wall, trunk in air sniffing, follows Opal	trunk sniff	Moves away from wall	walk
8			Exploring wall, nudges Opal through central gate	contact	Walks down to feeding gate	walk
9			Walks down to feeding gate too. Full circle on spot	walk / circle	Swaying from side to side, moving trunk along ground, waiting for food. Stops and starts again 50+ times, rhythmically	weave
10	13:15:00		Back leg raised; standing still, watching me	still	Swaying, trunk curls.	weave
11			Curls trunk up on top of head, lifts left ear, swinging tail	trunk sniff	Backs away from barrier, then goes back to sway more	walk, weave
12			Feels her left tusk, reaches up to left ear.	trunk sniff	(Visitors: "He's dancing")	
13			I speak to visitor, starts to walk in 2 big circles	circle	Still swaying	weave
14	13:30:00		Lifts back right leg, walks in circle again; trunk up to sniff	circle, trunk sniff		
15			Goes up to barrier	walk	Moves back up paddock to wall.	walk
16			Turns 2 circles, stops and stares, circling, stops with waving tail, trunk up smelling us	trunk sniff, circle	Foraging hay in mud, goes to wall, drops ball of food from mouth, lifts front left foot.	feed
17					Reaches up to top of wall, scratches right ear	trunk sniff
18			Stands trunk twisted, does circle and stands staring	circle	Feeding by wall	feed
19			Flops trunk over right tusk		Approaches Tanya	walk
20	13:45:00		Goes to feeding fence and stands sideways		Moves head down beside Tanya, than backs away, lifts right front leg	contact
21				still		
22	14:00:00		Stands watching us	still	Moves trunk over Tanya's eye and tusk. Continues swaying	contact, weave
23		*keeper puts straw at corner*				

+ ≣ 8 Jan 2014 ▾ 22 Jan 2014 ▾ 29 Jan 14 turn ▾ 5 Feb 2014 ▾ 19 Feb 2014 ▾ 20 Feb 2014 ▾ 14 May 2014 ▾

Figure 6: Example observations of Tanya and Opal, showing simultaneous behaviours and early categorization. Recorded from 13:00 to 14:00 on 8 Jan 2014.

We then constructed an overview of all recorded elephant behaviours during the period of the ethnographic study, using a combination of at-the-time written observations and subsequent detailed scrutiny of video recordings (see Figure 7: Notebook showing further observations).

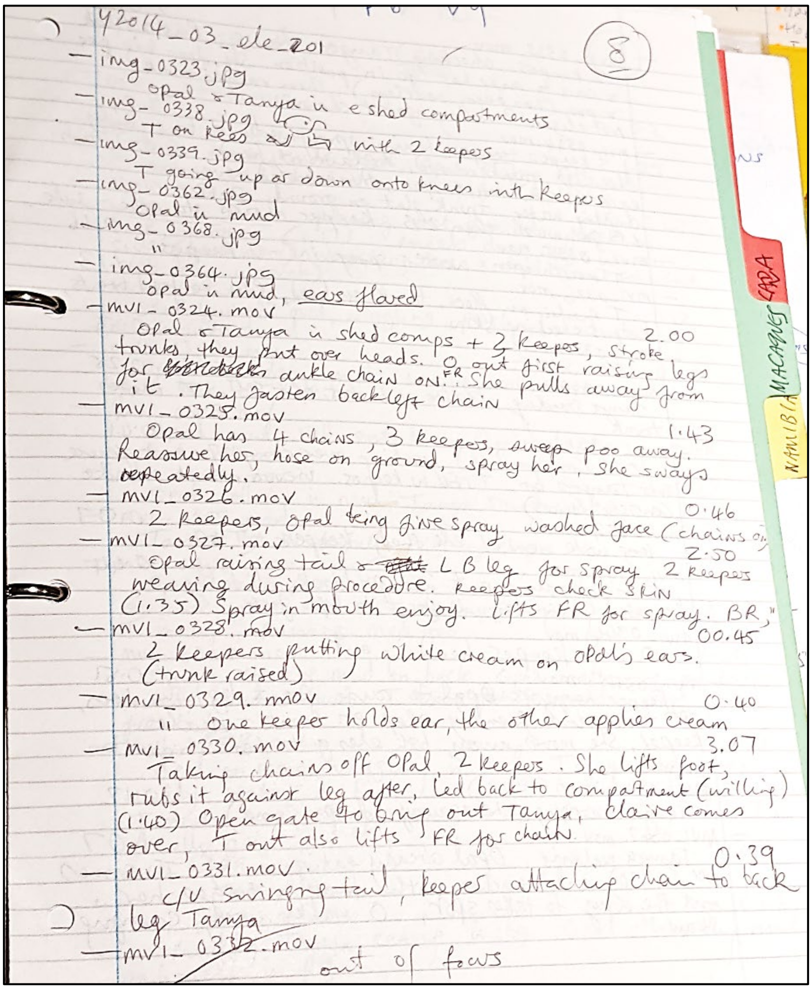

Y2014_03_ele_201 (8)
img_0323.jpg
Opal & Tanya in e shed compartments
img_0338.jpg
T on knees with 2 keepers
img_0339.jpg
T going up or down onto knees with keepers
img_0362.jpg
Opal in mud
img_0368.jpg
"
img_0364.jpg
Opal in mud, ears flared
mvi_0324.mov
Opal & Tanya in shed comps + 2 keepers, stroke 2.00
trunks, they put over heads. O put first raising legs
for ~~...~~ ankle chain on. FR She pulls away from
it. They fasten back left chain
mvi_0325.mov 1.43
Opal has 4 chains, 3 keepers, sweep poo away.
Reassure her, hose on ground, spray her, she sways
repeatedly.
mvi_0326.mov 0.46
2 keepers, Opal being give spray washed face (chains on
mvi_0327.mov 2.50
Opal raising tail & LB leg for spray 2 keepers
weaving during procedure. Keepers check skin
(1.35) Spray in mouth enjoy. Lifts FR for spray. BR"
mvi_0328.mov 00.45
2 keepers putting white cream on Opal's ears.
(trunk raised)
mvi_0329.mov 0.40
" One keeper holds ear, the other applies cream
mvi_0330.mov 3.07
Taking chains off Opal, 2 keepers. She lifts foot,
rubs it against leg after, led back to compartment (willing)
(1.40) Open gate to bring out Tanya, Claire comes
over, T out also lifts FR for chain
mvi_0331.mov 0.39
c/u swinging tail, keepers attaching chain to back
leg Tanya
mvi_0332.mov
out of focus

Figure 7: Page from notebook showing further observations taken from video clips - Opal and Tanya, March 2014

The collection of behaviours were categorized these into the following broad groups: food-related, social, playful, stereoscopic, keeper-oriented, audible. We made a note of which physical part of elephant was involved - trunk and/or full-body. We noted whether we thought a specific smell was involved and we attempted to identify specific triggers for behaviours if they were keeper oriented or associated with another elephant. We also marked the data for each elephant to see if there was any noticeable difference (see Figure 8).

At this point it became obvious that the behaviours displayed by all elephants were foraging behaviour, urinating, defecating, stereoscopic behaviour and associating closely with one another. The other behaviours were distributed amongst the elephants, showing that there was clear individuality within the group.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Action	food-related / forage	social	play	stereotypic	keeper-oriented	audible	body	trunk	smell	trigger	consequence	Zol	Tem	Tan	Opa	ALL
2	TOTALS	25	15	10	2	2	3	30	39	16	0	0	21	20	37	19	8
3																	
4	walk in circles	1			1			1							1	1	
5	weave head	1			1				1				1	1	1	1	1
6	walk to lower gate	1						1							1	1	
7	walk round pool	1						1									
8	walk to hay spot	1						1					1	1	1	1	1
9	walk to wall	1						1							1		
10	walk to boundary	1						1							1		
11	walk to top field	1						1							1		
12	clamber up over rocks	1						1							1		
13	go into pool	1		1				1					1		1		
14	back away							1									
15	raise 1 leg						1	1					1				
16	raise 2 legs (balance)							1					1				
17	follow keeper					1		1							1	1	
18	lift feet for keeper					1		1			request from keeper				1	1	
19	wave tail		1					1	1						1		
20	feel own eye with trunk								1						1		
21	feel back with trunk								1						1		
22	trunk over head								1		to follow keeper				1		
23	flap ears							1							2		
24	feel ear with trunk								1	1					1		
25	feel tusk with trunk								1	1					1		
26	flop trunk over tusk			1					1						1		
27	caress trunks		1	1					1	1			1	1			
28	tusks together, facing		1	1				1					1	1			
29	do poo												1	1	1	1	1
30	do pee								1				1	1	1	1	1
31	trunk through fence	1						1	1					1			
32	investigate muddy hole			1				1	1				1				
33	dig mud with foreleg			1				1					1			1	
34	head into mud			1				1	1							1	
35	spray dust on self			1				1	1								
36	spray mud on self			1				1	1							1	
37	sniff puddle							1	1	yes							
38	shake head and ears							1									
39	pick up large stick			1				1	1				1				
40	snort		1				1		1					2			
41	trumpet		1				1		1		Opal touch Tanya			1	1		
42	periscope trunk	1							1	1			1		2		
43	smell poo		1						1	1			1	1			
44	smell/touch other genitals		1						1	1							
45	smell/touch other ears		1						1	1							
46	smell/touch other inside mouth		1						1	1							
47	smell/touch other top of head		1						1	1							
48	smell/touch other eyes		1						1	1							
49	smell/touch other back		1						1	1							
50	scoop hay from pile	1							1				1	1	1	1	1
51	sweep trunk over ground	1							1	1			1	1	1	1	1
52	pick stuff from rocks	1							1				1	1	1	1	1
53	graze over fence (grass)	1							1				1				
54	hold clump of hay and select bits	1							1					1	1		
55	drink from pond	1							1				1				
56	drop food	1							1					1			
57	pick up dropped food	1							1						1		
58	take from visitor	1							1	1					2	2	
59	find cabbage etc after feed time	1							1	1					2	2	
60	smell hay before eating	1							1	1							
61	shake mud from hay before eating	1							1								
62	avoid walking on poo							1		1			1	1			
63	back away							1									
64	nudge conspecific out the way	1	1					1						1	1		
65	follow another elephant		1					1						1	1		
66	stand together		1										1	1	1	1	1
67																	
68																	
69																	
70																	

8 Jan 2014 | 22 Jan 2014 | 29 Jan 14 turn | 5 Feb 2014 | 19 Feb 2014 | 20 Feb 2014 | 14 May 2014 | overvi

Figure 7: Overview of categorised elephant behaviours at Colchester Zoo, showing which animal performed behaviour and whether it involved use of trunk.
Note: This does not show frequency, but whether behaviour was observed during the study.

A7: Media Links

During the time spent undertaking this research, I have maintained a blog – Interactive Toys for Elephants – that gives a regular account of visits to elephant facilities, elephant watching experiences, talks with keepers, prototype development and testing devices in the field. It has been live online since 2013, currently with over 50 posts. The blog also provides links to all the published work and public events associated with our research – papers, workshops, articles, talks.

The public Soundcloud repository contains personal audio samples and synthesized sounds developed for the project; other audio sources are referenced on the blog.

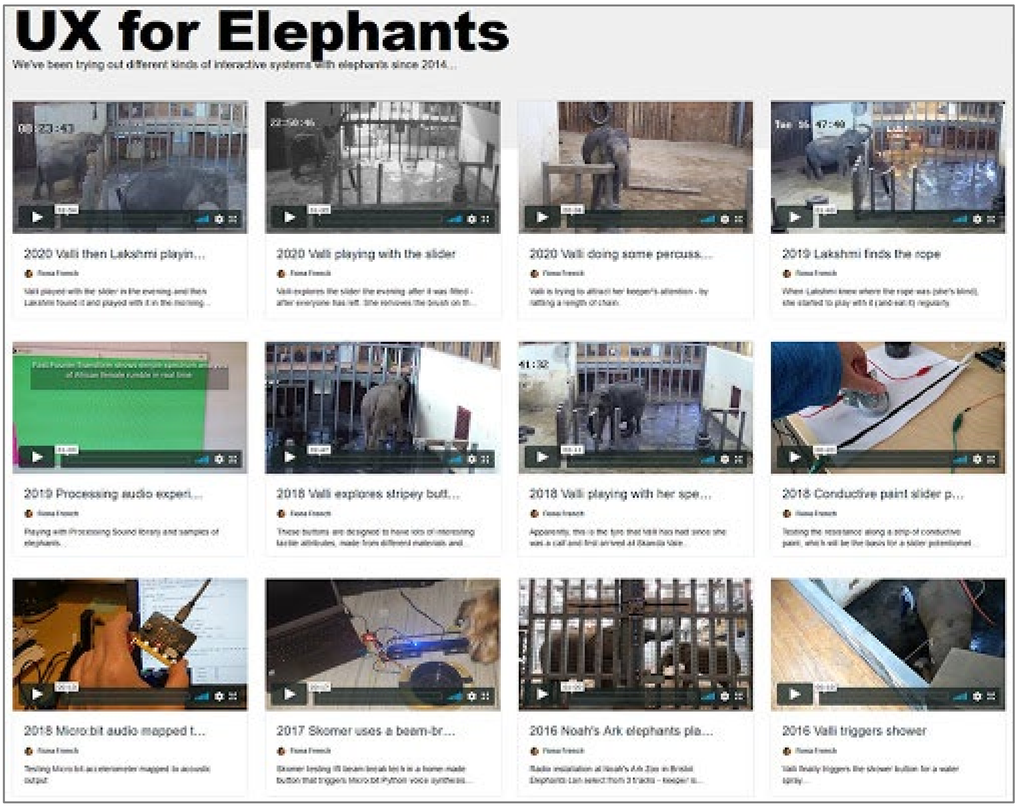
There is also a public video collection – UX for Elephants – that showcases 24 video clips from the work. These videos are short pieces taken from the repository of footage (several hours) taken in our workshop and with the Skanda Vale elephants from 2015-2020. They illustrate many of the examples we describe in the workbooks; for example, testing sensors and showing elephant reactions to novel interactive devices. A recent DIS conference video presentation is also included in this collection, as it offers an overview of our contribution to aesthetics and interaction design.

Finally, I have included a poem written in 2014, when I regularly travelled from London to Colchester on Wednesdays to undertake an ethnographic study of the elephants housed in Colchester Zoo.

- www.toys4elephants.blogspot.com

- Soundcloud album: https://soundcloud.com/user-607238008

- Vimeo UX for Elephants showcase: https://vimeo.com/showcase/6353326



Elephant Day

Same old tube, same old bus
Stay detached don't make a fuss
Same old grey crowd pouring down
Oozing out to face the frown
soft human toffee smoothly filling boxes
...
occasional urban foxes.

But Wednesday is Elephant Day.

Deep rumbles of love are sung at the morning greet
Zola drops her richly scented dung at Tembo's feet
Inhaling her perfume, he dribbles to his toes
Swinging and caressing with his elongated nose

please stand behind the yellow line
you'll be fine
please allow all travellers off the carriage before boarding
watch the hoarding
please stand well clear of the closing doors
just do your chores

but today is Elephant Day.

In the swirl of London faces, one huge head remains, staring at me. Blink.
Instead of a scarf, I am wearing the ghost of a coiling trunk.

Big ones and bigger ones
don't watch your figure ones
Never mind the enormous gap
Just imagine the shovels of slap
required to fill those those lovely wrinkles
Swathed in loose-fit leathery crinkles

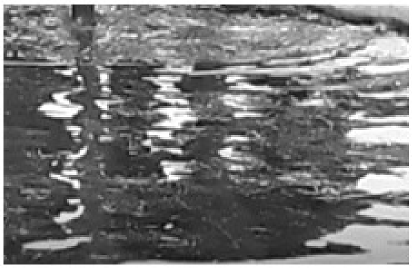
ladies and gentlemen
a good service is operating on all underground lines for your safety

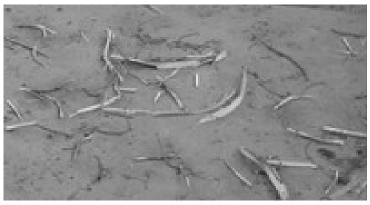
I shudder until paper cup coffee warms my January bones
rumination, contemplation, reflection

Today is Wednesday
and it is Elephant Day.

Wabi-Sabi

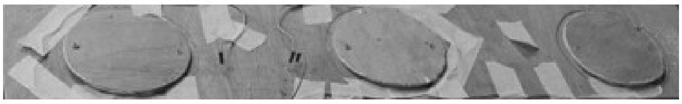
free





graceful

asymmetric



rough

transient

natural

tranquil

simple